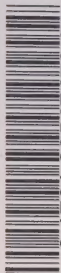


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**APPLICATION OF A MASS BALANCE MODEL
TO ASSESS THE EFFECTIVENESS OF FIVE REMEDIAL OPTIONS
FOR MOHAWK LAKE, BRANTFORD**

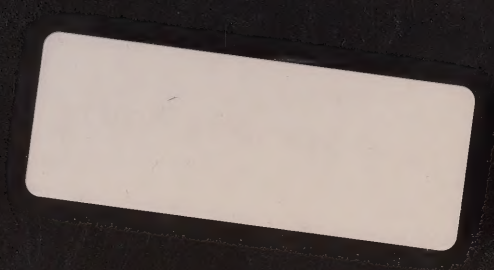
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Sherry Eaton

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APPLICATION OF A MASS BALANCE MODEL TO ASSESS THE EFFECTIVENESS OF FIVE REMEDIAL OPTIONS FOR MOHAWK LAKE, BRANTFORD

Degree: Master of Science
Year of Convocation: 1996
Department: Geography
University: University of Toronto

ABSTRACT

A simple steady-state mass balance model based on the QWASI fugacity/aquivalence model is developed for Mohawk Lake, Brantford, Ontario; a contaminated, urban lake. The QWASI model, along with the linear additivity principle (LAP), are used to assess the sources and fate of contaminants in the Lake, and the effectiveness of five remedial options. Two polynuclear aromatic hydrocarbons, benzo(a)pyrene and anthracene, are used as indicators of contaminant dynamics and remedial effectiveness. The five remedial scenarios are: (1) sediment capping, (2) installation of sediment traps at the end of stormsewers, (3) sediment dredging, (4) construction of a wetland, and (5) a combination of Options 2, 3 and 4 (sediment traps, wetland and dredging). The model provides order of magnitude estimates of chemical loadings, concentrations in water and sediment, amounts, rates, source and persistence for baseline conditions and each of the five remedial scenarios. The results of the model indicate that contaminant contributions via stormwater inflow is the primary factor influencing water quality in Mohawk Lake, and although the majority of contaminant in the system is present in the sediments, this historical/inplace source of pollutants has only a secondary impact on the water quality of Mohawk Lake. The results suggest that in order for any remedial option to be successful it must focus primarily on contaminants associated with stormwater inflow and, secondly, on historical/inplace pollutants. These priorities are reflected in the model's identification of Option 5 (combination of sediment traps, wetland and dredging) as the most effective remedial option for Mohawk Lake.

Key words - Mohawk Lake, mass balance, QWASI, polynuclear aromatic hydrocarbons, benzo(a)pyrene, anthracene, sediments, contaminants, remediation.

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1 INTRODUCTION

The quality of water and sediment in many urban aquatic systems is generally poor with contaminant concentrations often exceeding established quality objectives (Marsalek, 1995; Pitt et al., 1993; Barcia, 1992; U.S. EPA, 1983). Actions undertaken to address this degradation have typically focused on point sources of pollutants, such as stormsewers and industrial discharges, because they are obvious, quantifiable and controllable via policy and regulations (Murray, 1988; Ellis, 1988; Vigon, 1985). However, after the implementation of point source controls, it has been found in some cases that contaminants associated with in-place sediment are the primary factor responsible for poor water quality (Diamond, 1995). Prior to developing a remedial action plan for any aquatic system, it is therefore essential to not only characterize the nature and extent of contamination, but to quantify the extent to which current conditions are the result of present discharges and/or historic/in-place pollutants, the impact of in-place contaminants on the whole lake system, and the time required for the system to recover to an uncontaminated, or at least to an acceptable, state (Diamond et al., 1996; Diamond and Ling-Lamprecht, 1996; Diamond et al., 1994).

Multi-media mass balance models, such as the QWASI (Quantitative Water-Air-Sediment Interactions) model (Mackay, 1991; Mackay and Diamond, 1989; Mackay et al., 1983) are useful tools for addressing such considerations. In this study, a modified QWASI model is applied to Mohawk Lake, a small, contaminated, urban lake located in downtown Brantford, Ontario, Canada. The model is used to assess the sources and fate of contaminants in the system and the effectiveness of five remedial scenarios. The dynamics of two PAHs, benzo(a)pyrene (BaP) and anthracene, are used as indicators of the effectiveness of the remedial scenarios.

The primary objective of this research is to illustrate how the use of a mass balance model can improve our understanding of the sources and fate of pollutants in a contaminated lake and thus assist in the selection of the most effective remedial option. Based on available data, the model provides order of magnitude estimates of contaminant dynamics and is useful for quantifying point and non-point source contaminant contributions to the Lake, distinguishing between processes and factors that are of primary and secondary importance, identifying the most effective remedial options, and determining which aspects of the Lake are in need of further investigation. It should be noted that given the lack of, and uncertainties associated with some of the available data, and due to the use of averaged annualized conditions, the model developed for Mohawk Lake represents a screening level



FIGURE 2-1: Location of Mohawk Lake, Abandoned Landfills and Former Industrial Sites
(source: Ecological Services for Planning, 1994a)

- 1 Sewage Treatment Plant
- 2 Sonoco Papers
- 3 Robinson Reclamation
- 4 Starline
- 5 GO Viscation
- 6 Koenig Walrus
- 7 Former P.U.C. Building, Bradford Hamilton Electric Railway
- 8 Bradford Iron and Metal Scrap Yard
- 9 Republic Environmental Waste Mgmt.
- 10 Landfill Retention Pond
- 11 Lumber yard - former grain silos
- 12 Bissel Brewery
- 13 Canada Glue Company
- 14 Measey Varty Farm Equipment Works/Foundry
- 15 White Farm Equipment
- 16 Bradford Packers
- 17 Norton / Canadian Divers Abrasive
- 18 Former Gas Works
- Abandoned Landfill Sites (Gore & Storde Ltd. 1991)

Based on an annual average, the west canal receives 130 m³/h of inflow from Eastward Creek which discharges into the head of the west canal and consists primarily of storm drainage from areas to the north and west. The west canal receives another 162 m³/h of inflow from stormsewer discharges. The particulate flux associated with these stormwater inflows is estimated to be 500 tonnes per year (Gore & Storrie Limited, 1995a). The total outflow (accounting for precipitation and evaporation) from the Canal is 354 m³/h and represents the inflow to the lake. The lake receives another 22 m³/h of storm drainage. Total outflow from the lake (accounting for precipitation and evaporation) is 383 m³/h, representing a detention time of 23 days (Gore & Storrie Limited, 1995a). Outflow from the lake is controlled by a weir and discharges into a well defined stream which drops sharply into the Grand River located approximately 200 metres from the weir (M.M. Dillon, 1972).

Water in the canal and lake is characterized as highly turbid with relatively low dissolved oxygen levels. The turbid conditions of the lake are the result of high silt loadings from the canal, wind mixing and bioturbation (Gore & Storrie Limited, 1995b). Contaminants whose concentrations consistently exceed provincial water quality objectives include phosphorous, phenols, copper, zinc and coliform bacteria. Canal and lake sediments are characterized as highly organic and contaminated with both organic and inorganic pollutants, notably lead, zinc, copper, petroleum hydrocarbons and PAHs (Ecological Services for Planning, 1994a and 1994b).

3 DESCRIPTION OF REMEDIAL OPTIONS

In 1994, the City of Brantford received a \$6 million grant from the Province of Ontario to rehabilitate Mohawk Lake. As a result, several studies were carried out on behalf of the City in preparation for the Lake's rehabilitation (Ecological Services for Planning, 1994b; Gore & Storrie Limited, 1995a, 1995b and 1995c; Golder Associates, 1994). Several preliminary remedial options were identified including sediment capping, implementation of stormwater best management practices (e.g., increased street sweeping, installation of sediment traps at stormsewer outfalls discharging to the lake and canal, sewer rehabilitation, public education, etc.), partial or complete dredging of sediments from the canal and/or lake, construction of a wetland at the mouth of the canal, and various combinations of the above. None of these options were, however, evaluated in detail or implemented due to the withdrawal of provincial funding.

For the purpose of modelling the various remedial options, five representative scenarios were selected. These include: (1) sediment capping, (2) sediment traps at the end of stormsewers outfalls

discharging into the canal, (3) construction of a wetland in the mouth of the canal, (4) complete dredging of sediments, and (5) a combination of sediment traps, wetland construction and complete dredging. Each of these options is described briefly below.

Sediment capping consists of a stabilization process where additives, such as cement, lime and/or polymer mixtures, are combined or injected into the upper sediments. The purpose of sediment capping is to improve water quality through a reduction in sediment resuspension and contaminant diffusion (Gore & Storrie Limited, 1995c).

Sediment traps are engineered devices that are installed either along stormsewer pipes or as large detention tanks or ponds at the end of the stormsewer in order to remove solid material and associated contaminants from stormwater prior to discharge. Solids removal in the range of 50-70% is possible with sediment traps, with removal rates as high as 90% achieved in some locations (Marsalek, 1995; Urbonas, 1994).

Constructed wetlands serve a function similar to sediment traps but provide a longer retention time and solids removal of 40 to 90% (Urbonas, 1994). The wetland considered for Mohawk Lake was to be located at the mouth of the canal thus providing treatment of the canal water prior to it entering the lake, and was to be designed with a solids removal efficiency of approximately 70% (Gore & Storrie Limited, 1995a).

Dredging serves to reduce or eliminate in-place contaminants through the removal of sediments. Additional benefits associated with dredging include increased water depth, increased water retention time, and habitat improvement (Peterson, 1994). Pilot testing in the Lake indicated that dredging could be carried out successfully with minimal immediate impacts to water clarity (Gore & Storrie Limited, unpublished data).

The combination of sediment traps, dredging and the wetland was intended to compound the benefits of all three options. The combination of these three options was selected since they represent those options that are technically feasible, and since they address both in-place and inflow contaminant sources.

Polycyclic aromatic hydrocarbons (PAHs) are organic substances made up of carbon and hydrogen atoms grouped into two or more fused benzene rings (Baek et al., 1991). PAHs are characterized by their low water solubilities, low vapour pressures and relatively high octanol-water partition coefficients (Environment Canada and Health Canada, 1994). PAHs represent a significant environmental concern as a result of their persistent, stable, ubiquitous, and in some cases, carcinogenic nature (Kayal and Connell, 1989).

Sources of PAHs to the environment include both combustion related processes such as incineration, open burning, power generation, industrial processes and automobile exhaust, as well as the direct release of products and by-products containing PAHs such as petroleum (e.g., large scale spills and chronic releases by automobiles), and creosote (Hoffman et al., 1984). In the urban environment, PAHs which accumulate on impervious surfaces (via deposition of particulates to which PAHs preferentially adsorb and via releases losses of PAH-associated products) are subsequently transported via urban stormwater runoff and are eventually deposited into the aquatic environment, where sedimentation represent the final environmental sink for PAHs (Baek et al., 1991; Environment Canada and Health Canada, 1994). A recent assessment of PAHs carried out by Environment Canada and Health Canada (1994) concluded, based on scientific data relating to the impact of PAHs on aquatic biota, that PAHs in Canada are considered to be entering the environment in quantities or concentrations that are having a harmful effect.

PAHs were selected as indicator compounds for assessing the effectiveness of the remedial options for Mohawk Lake since their presence and concentrations in Mohawk Lake are of concern. As well, it is thought that several sources, in addition to stormwater discharges, are or have contributed to the presence of PAHs in Mohawk Lake. These include the former coal gasification plant, wastewaters discharged to the Lake by several former industries located adjacent to the lake, and erosion from contaminated sites and abandoned landfills.

Benzo(a)pyrene was selected as an indicator compounds since it represents the higher molecular weight PAHs (i.e., those composed of four or more rings) and anthracene was selected since it represents the lower molecular weight PAHs (i.e., those with fewer than four rings).

The model developed for Mohawk Lake is a multi-compartment version of the Quantitative Water-Air-Sediment Interactions (QWASI) model developed by Mackay and coworkers. The QWASI model and associated concepts are fully described in Diamond (1995), Mackay (1991), Mackay and Diamond (1989), and Mackay et al. (1983). A brief description of the QWASI model is provided below.

The Mohawk Lake QWASI model is based on fugacity, an interphase equilibrium criterion, but uses an alternative equilibrium, "equivalence", since it is suitable for both volatile and non-volatile chemicals. Unlike chemical potential which is logarithmically related to concentration, fugacity (f , Pa) and equivalence (Q , mol/m³) are linearly related to concentration (C , mol/m³) through a proportionality constant, Z' (mol/Pa·m³) or Z (dimensionless), respectively. Z' and Z express the capacity of a specific phase for a specific chemical (i.e., $C = fZ' = QZ$), and are functions of the nature of the chemical and the phase properties. The ratio of the two Z' or Z values is the dimensionless partition coefficient (K_{12}) between the two phases.

In the case of fugacity, Z' values are calculated using the Z' value for air (Z'_A) which is calculated as $1/RT$, where RT is the gas constant temperature group (mol/Pa · m³). Z' values for other phases are then calculated using partition coefficients for air to water, water to sediment, etc. (i.e., if Z'_A and an air-water partition coefficient, K_{AW} , are known, then Z'_w for water is Z'_A/K_{AW}). The use of fugacity as an equilibrium criterion is suitable for chemicals that can establish a measurable concentration in the vapour phase (i.e., most organics). For chemicals that have a negligible or zero vapour pressure (most metals, organometals, ionic compounds and some organics), Z values are calculated using the Z value for water (Z_w) which is defined as 1.0. Subsequent Z values are obtained by multiplying Z_w by partition coefficients (i.e., Z_s , sediment, is the product of Z_w and the dimensionless sediment-water partition coefficient, K_{sw} , or simply K_{sw} since Z_w is equal to 1.0).

In order to express rates of chemical movement or reaction, a D value (m³/h, a transport and transformation parameter) is defined. There are three types of D values. First for chemical transport by advective flow, D is expressed as GZ , where G is the phase flow rate (m³/h) and Z is the fugacity or equivalence capacity (mol/Pa · m³ for Z' and dimensionless for Z). Second, for chemical transport by diffusion, D is defined as KAZ , where K is a mass transfer coefficient (m/h) and A is area (m²). Finally, D for chemical transformation is equal to VkZ , where V is the compartment volume (m³),

and k is a first order rate constant (h^{-1}). The rate of chemical movement or reaction, N (mol/h or kg/y), then becomes the product of D and Q .

The QWASI model developed for Mohawk Lake is based on the equivalence approach since, although two organic compounds are modelled, calibration of the model using an inorganic chemical was required due to data availability. Ultimately, both fugacity and equivalence mass balance equations are algebraically identical (Ling et al., 1993).

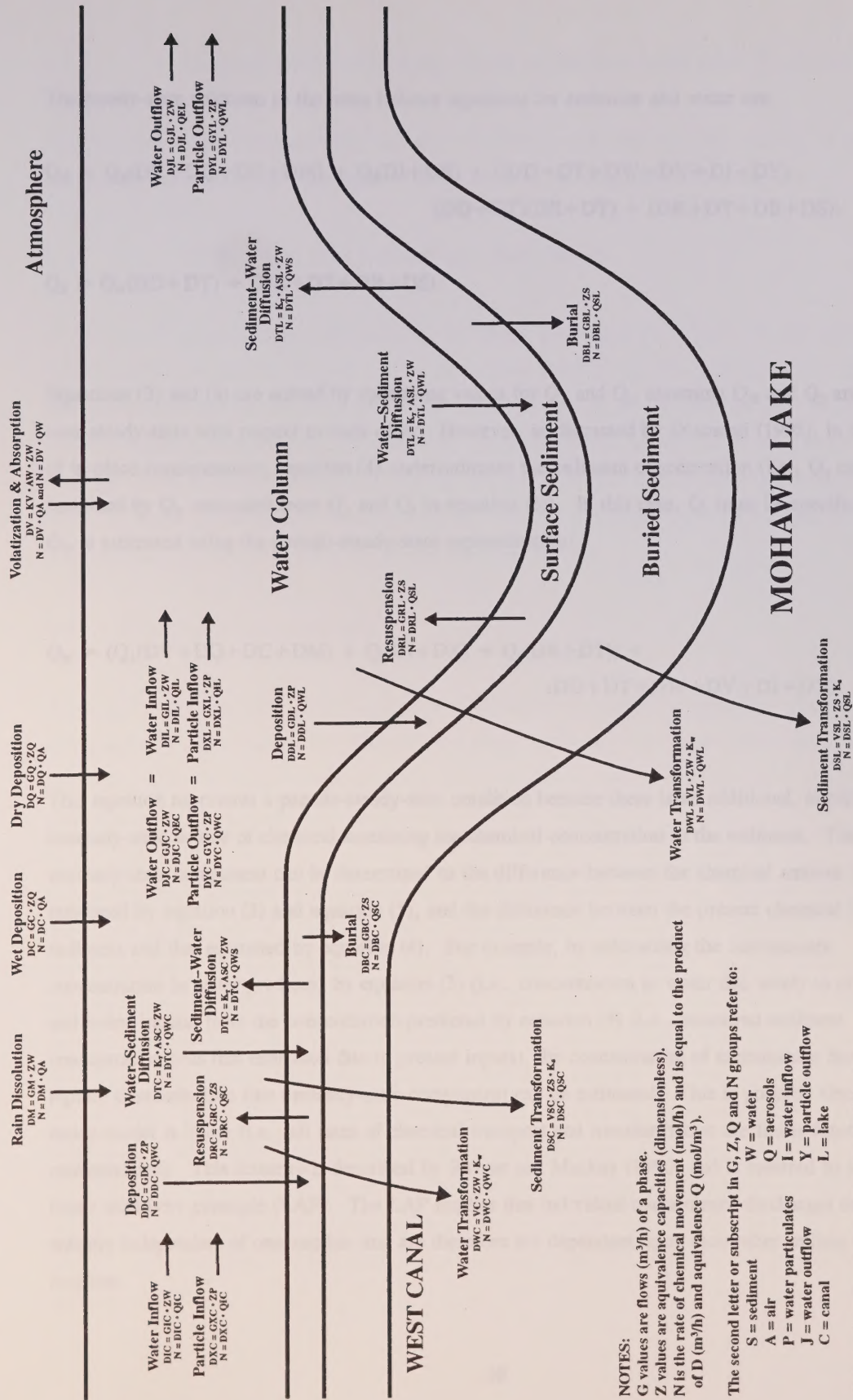
For modelling purposes, Mohawk Lake was segmented into two geographic units: (1) the west canal, and (2) the lake (see Figure 2-1). The Lake was segmented since the canal and lake are distinct geographically and limnologically. Each segment consists of three primary well mixed compartments: air, water and sediment. The air compartment consists of air, aerosols and rainwater. The water compartment contains water, dissolved and particulate organic and mineral matter. The sediment compartment consists of an upper active layer and lower buried or inaccessible layer. The active layer is composed of particulate organic and mineral matter, and pore water. Each individual compartment is in equilibrium (equal equivalence) but not in equilibrium with the other compartments. Figure 5-1 illustrates the compartments and associated processes included in the Mohawk Lake QWASI model.

Based on the above information, steady- and unsteady-state mass balance equations for estimating chemical fate in the model compartments are then established and solved. The mass balance equations for water and sediment are:

$$V_w Z_w dQ_w/dt = Q_A(DV+DQ+DC+DM) + Q_I(DI+DX) - Q_w(DD+DT+DW+DV+DJ+DY) + Q_s(DR+DT) \quad (1)$$

$$V_s Z_s dQ_s/dt = Q_w(DD+DT) - Q_s(DR+DT+DB+DS) \quad (2)$$

where Q is equivalence (mol/m^3), with the subscripts W, I, A, and S referring to water, inflow, air and sediment respectively. D values are defined on Figure 5-1 and listed on Table 6-4.



NOTES:

G values are flows (m^3/h) of a phase.

Z values are equivalence capacities (dimensionless).

N is the rate of chemical movement (mol/h) and is equal to the product of D (m^3/h) and equivalence Q (mol/m^3).

The second letter or subscript in G, Z, Q and N groups refer to:

- S = sediment
- A = air
- P = water particulates
- I = water inflow
- J = water outflow
- C = canal

K_T is a sediment-water mass transfer coefficient.

K_V is an overall air-water mass transfer coefficient.

K_s and K_w are sediment and water reaction rate constants (h^{-1}).

AW and AS are air-water and water-sediment areas (m^2).

V indicates volume.

FIGURE 5-1: Model of Mohawk Lake Illustrating Compartments and Associated Processes

The steady-state solutions to the mass balance equations for sediment and water are:

$$Q_w = \frac{Q_A(DV+DQ+DC+DM) + Q_i(DI+DX)}{(DD+DT)(DR+DT) \div (DR+DT+DB+DS)} - \quad (3)$$

$$Q_s = \frac{Q_w(DD+DT)}{(DR+DT+DB+DS)} \quad (4)$$

Equations (3) and (4) are solved by specifying values for Q_A and Q_i , assuming Q_w and Q_s are at or near steady-state with respect to each other. However, as discussed by Diamond (1995), in the case of in-place contamination, equation (4) underestimates the sediment concentration (i.e., Q_s can not be sustained by Q_w estimated from Q_A and Q_i in equation (3)). In this case, Q_s must be specified and Q_w is estimated using the pseudo-steady-state approximation:

$$Q_w = \frac{(Q_A(DV+DQ+DC+DM) + Q_i(DI+DX) + Q_s(DR+DT))}{(DD+DT+DW+DV+DJ+DY)} \quad (5)$$

This equation represents a pseudo-steady-state condition because there is an additional, implicit unsteady-state source of chemical sustaining the chemical concentration in the sediment. This unsteady-state component can be determined as the difference between the chemical amount in water estimated by equation (3) and equation (5), and the difference between the present chemical burden in sediment and that estimated by equation (4). For example, by subtracting the contaminant concentration in water predicted by equation (3) (i.e., concentration in water due solely to present air and water inputs) from the concentration predicted by equation (5) (i.e., measured sediment concentration plus that estimated due to present inputs), the concentration of contaminant due solely to in-place contamination (the unsteady-state component) can be estimated. This is possible since the entire model is linear (i.e., all rates of chemical transport and transformation are linear functions of concentration). This linearity is described by Striver and Mackay (1990) and is referred to as the linear additivity principle (LAP). The LAP implies that individual contaminant discharges behave entirely independent of one another and are therefore not dependant upon each other in time or location.

A steady-state model of annual conditions was assembled to obtain a time averaged view of chemical dynamics in Mohawk Lake. Six stages of data collection and assessment were required:

6.1 Hydrologic and Limnologic Parameters

The values of system specific hydrologic and limnologic parameters required for the Mohawk Lake QWASI model are listed in Table 6-1. For the purpose of the model, the sediment-water area was assumed to equal the water surface area. The active sediment depth was determined based on sediment coring carried out and documented by Golder Associates (1994). Rates of sediment burial were calculated based on the length of time required for sediments to accumulate and were adjusted based on model calibration (see discussion below). The organic content of suspended particle inflow and suspended particles was assumed, as was sediment porosity.

6.2 Chemical Contributions

Atmospheric loadings were based on atmospheric concentrations of 0.005 ng/m^3 BaP (Ling et al., 1993) and 0.06 ng/m^3 anthracene (McVeety and Hites, 1988) and were determined to be $1.4 \times 10^{-5} \text{ kg/y}$ and $2.0 \times 10^{-4} \text{ kg/y}$ BaP to the canal and lake, respectively, and $1.6 \times 10^{-3} \text{ kg/y}$ and $2.2 \times 10^{-2} \text{ kg/y}$ anthracene to the canal and lake, respectively.

Concentrations in stormwater inflows and the one tributary to the canal (i.e., Eastward Creek) were assumed to be the same since the creek flow consists primarily of stormwater runoff (Gore & Storrie, unpublished data). Stormwater concentrations of 104 ng/L for BaP and 137 ng/L for anthracene, as reported by Aquafor Beech (1994) in their Metro Toronto wet weather outfall study, were assumed to represent concentrations in stormwater discharging to the canal. Concentrations in the inflow to the lake from the canal were assumed to be equal to the concentration in the canal water, as determined by the model. BaP loadings due to total water inflows (tributary and stormwater inflows) were determined to be 0.49 kg/y to the canal and 0.18 kg/y to the lake under steady-state conditions, and 0.19 kg/y to the lake under pseudo-steady-state conditions. Anthracene loadings due to total water inflow were estimated to be 0.43 kg/y to the canal, 0.12 kg/y to the lake under steady-state conditions and 0.17 kg/y to the lake under pseudo-steady-state conditions. There are no industrial emissions to Mohawk Lake.

TABLE 6-1: System Specific Hydrologic and Limnologic Values

	Units	West Canal	Lake	Source
Dimensions				
Water surface area	m ²	11,000	139,000	(1)
Water depth	m	0.69	1.75	(2)(3)
Water volume	m ³	7,590	243,250	*
Sediment-water area	m ²	11,000	139,000	**
Active sediment depth	m	0.25	0.25	(4)
Active sediment volume	m ³	2,750	34,750	*
Water Flows				
Water inflow (tributary)	m ³ /h	130	354	(1)
Stormsewers	m ³ /h	162	22	(1)
Rain	mm/y	855	855	(1)
Evaporation	mm/y	728	728	(1)
Water outflow	m ³ /h	354	383	(1)
Suspended Particle Properties				
Density	g/cm ³	1.31	1.4	(5)
Organic carbon content	g/g	0.2	0.09	**
Volume fraction of water	-	3.7x10 ⁻⁴	3.5x10 ⁻⁴	*
Volume fraction of inflow	-	2.46x10 ⁻⁴	3.3x10 ⁻⁴	*
Sediment Properties				
Sediment density	g/cm ³	1.3	1.3	(4)
Sediment porosity	-	0.95	0.95	**
Sediment organic carbon content	g/g	0.1	0.06	(2)(3)
Particle Flows and Movement				
Suspended particles - tributary	mg/L	600	490	(1)
Suspended particles - stormsewers	mg/L	100	100	(1)
Particle outflow	mg/L	490	550	(1)
Sediment burial	g/m ² /d	745	117.5	*
Sediment resuspension	g/m ² /d	5	7.5	*
Sediment deposition	g/m ² /d	750	125	*
Atmosphere Properties				
Density of Aerosols	g/cm ³	1.5	1.5	(6)
Concentration of aerosols	ug/m ³	30	30	(6)
Volume fraction of aerosols	-	2.3x10 ⁻¹¹	2.3x10 ⁻¹¹	*
Deposition velocity	cm/s	0.3	0.3	(6)
Scavenging ratio	-	2.0x10 ⁵	2.0x10 ⁵	(6)
Dry particle deposition	m ³ /h	2.7x10 ⁻⁶	2.2x10 ⁻⁵	*
Wet particle deposition	m ³ /h	4.9x10 ⁻⁶	6.2x10 ⁻⁵	*

Data sources:

- * Calculated value.
- ** Assumed value.
- (1) Gore & Storrie Limited, 1995a; measured values.
- (2) Ecological Services for Planning, 1994a; measured values.
- (3) Ecological Services for Planning, 1994b; measured values.
- (4) Golder Associates, 1994; observed values.
- (5) Mackay, 1991; assumed value.
- (6) Ling et al., 1993; assumed value.

Sediment concentration used in the pseudo-steady-state estimation of water concentrations of 600 ng/g BaP in the canal, 7200 ng/g BaP in the lake, 200 ng/g anthracene in the canal and 620 ng/g anthracene in the lake were obtained from Ecological Services for Planning (1994a and 1994b).

6.3 Chemical Specific Data

Chemical specific data are summarized in Table 6-2 and were obtained from Ling et al. (1993) and Mackay et al. (1992).

6.4 Partitioning, Transport and Transformation Properties of Chemicals Between Media

Aquivalence Z values are presented in Table 6-3 and are based on Ling et al. (1993), Mackay (1991) and Mackay and Diamond (1989). D values are presented on Table 6-4. The expressions used to determine the D values are indicated on Figure 5-1.

6.5 Calibration of the Model

The steady-state model of Mohawk Lake could not be calibrated or tested using BaP or anthracene due to insufficient data relating to inflow and water concentrations. Instead, the model was calibrated for zinc for which loading and concentration data were available (Gore & Storrie Limited, 1995a; Ecological Services for Planning, 1994a and 1994b). Correspondence between measured and model estimates was achieved by adjusting rates of burial, resuspension and deposition. Due to the presence of historical/inplace contaminants associated with the sediments, the pseudo-steady-state model was used for calibration. Table 6-5 provides a summary of the measured zinc concentrations, model input adjustments and results associated with model calibration.

6.6 Parameterization of Remedial Options

In order to determine the effect of the various remedial options on contaminant dynamics in Mohawk Lake, changes were made to the baseline model conditions that were reflective of the changes that would occur in the canal and lake upon implementation of the remedial option. Modifications applied to baseline conditions for each remedial scenario are summarized on Table 6-6.

TABLE 6-2: Physical-Chemical Properties and Mass Transfer Coefficients

Variable	Unit	BaP	Source	Anthracene	Source
System temperature	°C	25		25	
Molecular mass	g/mol	252	(1)	178.24	(3)
Solubility	g/m ³	0.002	(1)	0.075	(3)
Vapour pressure	Pa	6.0x10 ⁻⁸	(1)	1.44x10 ⁻³	(3)
Melting point	K	452	(1)	216.2	(3)
Henry's law constant	Pa · m ³ /mol	0.0078	(1)	6	(3)
log K _{OW}	-	6.31	(2)	4.45	(4)
K _{OW}	-	2.1x10 ⁶	(2)	2.8x10 ⁴	(4)
Air-water partition coefficient (K _{AW})	-	3.3x10 ⁻⁶	*	2.5x10 ⁻³	*
Aerosol-air partition coefficient (K _{OA})	-	5.34x10 ¹⁵	*	5.4x10 ¹¹	*
Suspended particle-water partition coefficient (K _{PW})	-	2.24x10 ⁵	*	3.0x10 ³	*
Inflow particle-water partition coefficient (K _{PI})	-	1.12x10 ⁵	*	1.5x10 ³	*
Sediment-water partition coefficient (K _S)	-	1.11x10 ⁵	*	1.5x10 ³	*
Water reaction half-life (k)	h ⁻¹	1.0x10 ⁴	(2)	1.0x10 ³	(4)
Sediment reaction half-life (k)	h ⁻¹	3.0x10 ⁴	(2)	1.0x10 ⁶	(4)
Mass Transfer Coefficients (K):					
volatilization air-side	m/h	1	(2)	2.9	(4)
volatilization water-side	m/h	0.01	(2)	0.001	(4)
sediment water diffusion	m/h	2.7x10 ⁻⁶	*	2.8x10 ⁻⁶	*

* calculated value

(1) Ling et al., 1993; based on measured value.

(2) Ling et al., 1993; estimated or assumed value.

(3) Mackay et al., 1992; based on measured value.

(4) Mackay et al., 1992; estimated or assumed value.

TABLE 6-3: Equivalence Z Values (dimensionless)

Phases	Z Value	BaP	Anthracene
Water	ZW	1	1
Air	ZA	3.3x10 ⁻⁶	2.5x10 ⁻³
Aerosols	ZQ	1.8x10 ¹⁰	1.37x10 ⁹
Inflow suspended particles	ZPI	1.1x10 ⁵	1.5x10 ³
Water suspended particles	ZP	2.2x10 ⁵	3.0x10 ³
Sediment resuspension	ZR	1.1x10 ⁵	1.5x10 ³
Sediment	ZS	1.1x10 ⁵	1.5x10 ³
Bulk air	ZBA	0.04	3.0x10 ⁻²
Bulk inflow water	ZBWI	28.6	1.3
Bulk water	ZBW	84.9	2.13
Bulk sediment	ZBS	1.1x10 ⁵	1.4x10 ³

TABLE 6-4: Equivalence D Values (m³/h)

Process	D Value	Canal		Lake	
		BaP	Anthracene	BaP	Anthracene
Water inflow	DI	292	292	376	376
Water outflow	DJ	354	354	383	383
Particle inflow	DX	1.5x10 ⁴		9.5x10 ³	9.47x10 ³
Particle outflow	DY	2.9x10 ⁴	401	1.6x10 ⁴	1.62x10 ⁴
Rain dissolution	DM	1.07	1.07	1.36	13.6
Wet deposition	DC	7.8x10 ⁴	5.88x10 ³	1.1x10 ⁶	9.58x10 ⁵
Dry deposition	DP	4.2x10 ⁴	3.3x10 ³	4.0x10 ⁵	3.54x10 ⁵
Sediment deposition	DD	5.9x10 ⁴	794	5.6x10 ⁴	5.6x10 ⁴
Sediment resuspension	DR	196	2.05	2.2x10 ³	2.23
Sediment burial	DB	2.9x10 ⁴	395	3.5x10 ⁴	3.5x10 ⁴
Volatilization	DV	3.6x10 ⁻²	9.68	0.459	0.46
Sediment-water diffusion	DT	3.0x10 ⁻²	3.0x10 ⁻²	0.382	0.382
Water degradation	DW	44.7	11.2	667	667
Sediment degradation	DS	6.7x10 ³	2.7	5.1x10 ⁴	5.1x10 ⁴

TABLE 6-5: Results of Model Calibration for Zinc

	Initial Conditions	Adjust.1	Adjust.2	Adjust.3	Adjust.4	Adjust.5	Final Conditions	Actual
Canal								
Burial rate (g/m ² /d)	450	600	725	745	-	-	745	300*
Resuspension rate (g/m ² /d)	300	150	25	5	-	-	5	
Deposition rate (g/m ² /d)	750	750	750	750	-	-	750	
Water inflow (ug/L)	25	25	25	25	-	-	25	25**
Water (ug/L)	147	82.5	28.5	19.8	-	-	19.8	20**
Sediment (ug/g)	517	517	517	517	-	-	517	517
Lake								
Burial rate (g/m ² /d)	75	-	-	50	115	117.5	117.5	50*
Resuspension rate (g/m ² /d)	50	-	-	75	10	7.5	7.5	
Deposition rate (g/m ² /d)	125	-	-	125	125	125	125	
Water inflow (ug/L)	147	-	-	19.8	19.8	19.8	19.8	20**
Water (ug/L)	268	-	-	360	51.7	39.9	39.9	40**
Sediment (ug/g)	743	-	-	743	743	743	743	743

* estimated value, based on length of time for current sediments to accumulate, Gore & Storrie Limited, unpublished data.

** data available for only one sampling occasion, Ecological Services for Planning, 1994a.

TABLE 6-6: Model Parameterization Changes Reflective of the Five Remedial Options

Remedial Option	Canal	Lake	Source
Option 1: Sediment Capping	Decrease active sediment depth Decrease resuspension by 50%	Decrease active sediment depth Decrease resuspension by 50%	* **
Option 2: Sediment Traps	Decrease particulate inflow by 70% Decrease stormwater particulate inflows by 70% Decrease particulate outflow by 70% Decrease suspended particulates by 50% Decrease burial by 30%	Decrease particulate inflow by 70% Decrease stormwater particulate inflows by 70% Decrease particulate outflow by 70% Decrease suspended particulates by 50% Decrease burial by 30%	(1) (1) (1) ** *
Option 3: Dredging	Increase water depth Decrease active sediment depth Decrease resuspension by 50%	Increase water depth Decrease active sediment depth Decrease resuspension by 50%	(2) ** **
Option 4: Wetland	No change	Decrease particulate inflow by 75% Decrease particle outflow by 75% Decrease sediment burial by 75% Decrease sediment resuspension by 75% Decrease suspended particles by 75%	(1) (1) * ** **
Option 5: Dredging, Wetland and Sediment Traps	Increase water depth Decrease active sediment depth Decrease particulate inflow by 70% Decrease stormwater particulate inflows by 70% Decrease particulate outflow by 70% Decrease suspended particulates by 50% Decrease burial by 30% Decrease resuspension by 50%	Increase water depth Decrease active sediment depth Decrease particulate inflow by 70% and 75% Decrease stormwater particulate inflows by 70% and 75% Decrease particulate outflow by 70% and 75% Decrease suspended particulates by 50% and 50% Decrease burial by 30% and 75% Decrease resuspension by 50% and 75%	(2) * (1) (1) (1) ** * **

* calculated value

** assumed value

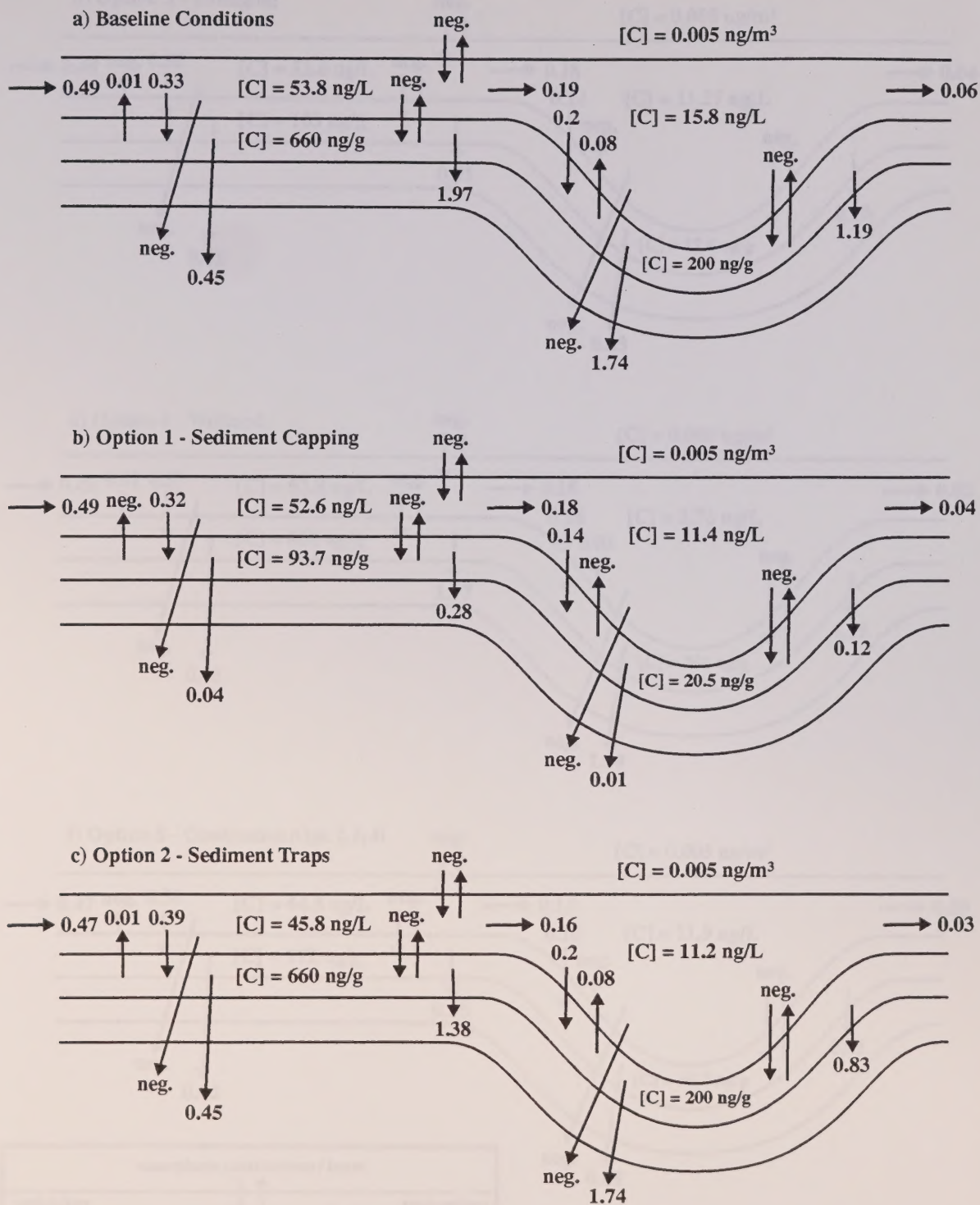
(1) Gore & Storrie Limited, 1995a; estimated value.

(2) Ecological Services for Planning, 1994a and 1994b; estimated value.

In the case of Option 1, sediment capping, it was assumed that a 2 year period had passed since capping of the sediments and that historical sediments had been completely isolated (i.e., no contributions due to resuspension of historical contaminants) in order to reflect near steady-state conditions. Under the dredging scenario (Option 3), water depth is increased by an amount corresponding to the depth of sediment removed, and as assumed for the sediment capping scenario, the historical contaminants had been completely removed. No changes were made to the canal's baseline conditions under the wetland scenario since the wetland is constructed at the end of the canal/mouth of the lake. Changes to baseline conditions under Option 5 represent a combination of parameterization changes reflective of each of the sediment traps, dredging and wetland scenarios. It should be noted that except for contaminant contributions from sediments (i.e., pseudo-steady-state conditions), it was assumed that each scenario represents steady-state or near-steady-state conditions. Accumulation of inflow contaminants over time was not considered by the model.

7 RESULTS AND DISCUSSION

Figures 7-1 and 7-2 illustrate the process rates and compartment concentrations for BaP and anthracene under baseline conditions and each of the five remedial scenarios. Tables 7-1 and 7-2 provide a summary of measured sediment and estimated concentrations of BaP and anthracene in the water for baseline conditions, as well as a comparison of estimated water and sediment concentrations associated with each of the remedial scenarios. Tables 7-3 and 7-4 summarize the total amount of BaP and anthracene in each compartment, as well as the estimated chemical persistence within the lake and canal. Appendix A contains a summary of the main process rates affecting BaP and anthracene in the canal and lake, as well as a comparison of each remedial option with baseline conditions. Appendix B contains an example of the model spreadsheet for canal and lake baseline conditions for BaP and anthracene under steady-state conditions.



**FIGURE 7-1: Estimated Rates of BaP Movement (kg/y)
and Compartment Concentrations For Baseline
Conditions and Remedial Scenarios
(neg. = negligible = $<10^{-3}$ kg/y)**

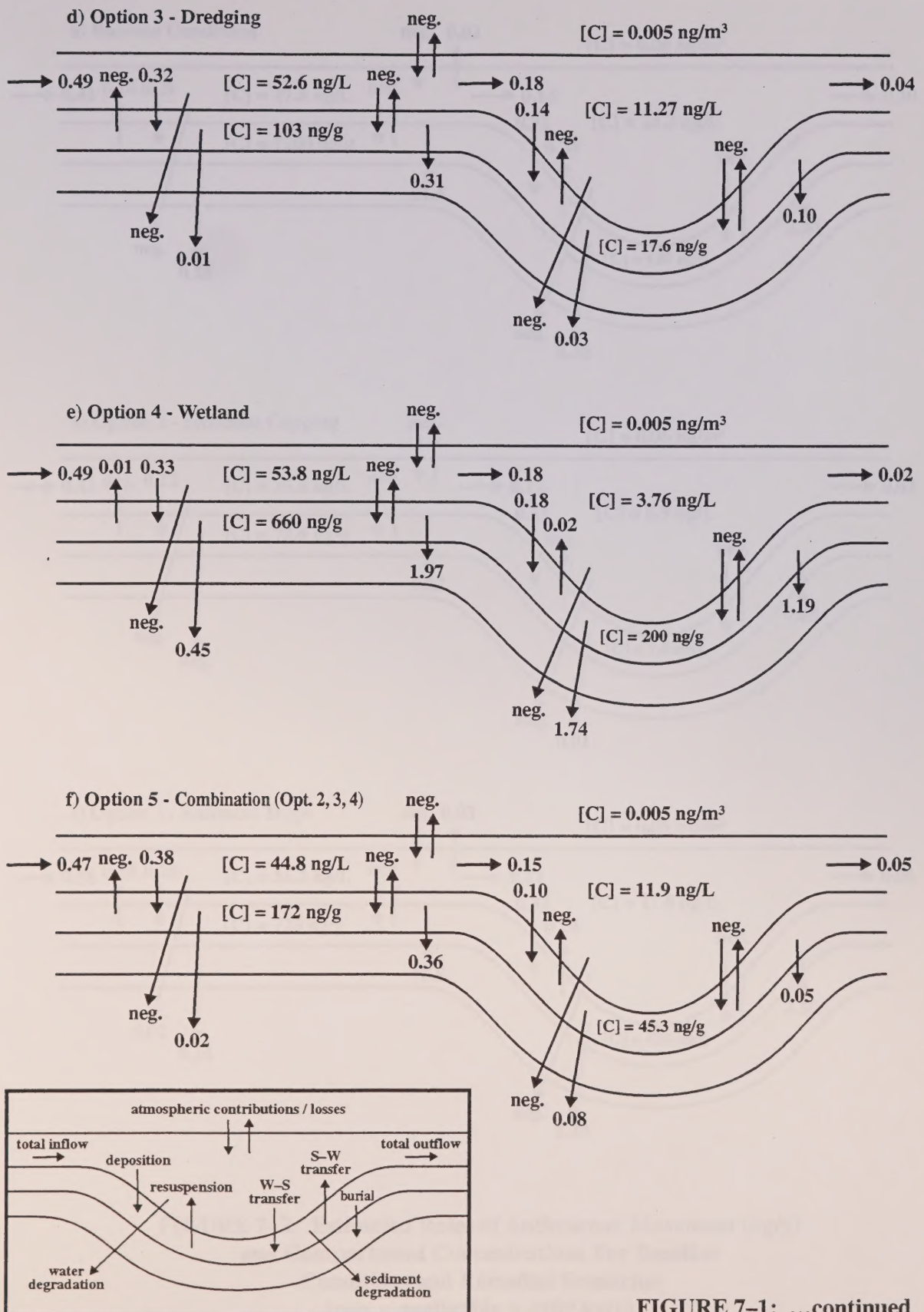


FIGURE 7-1: ...continued

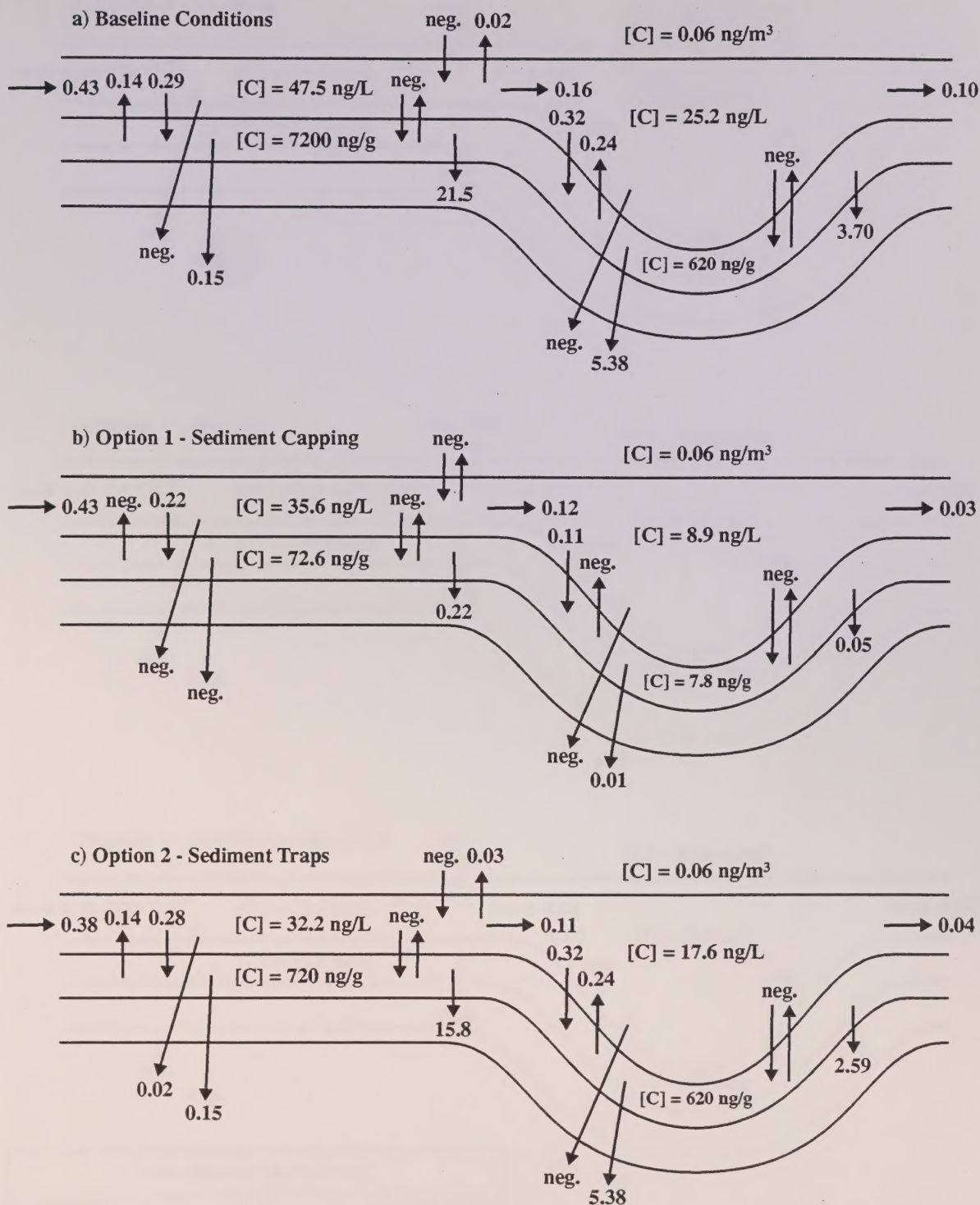


FIGURE 7-2: Estimated Rates of Anthracene Movement (kg/y) and Compartment Concentrations For Baseline Conditions and Remedial Scenarios
(neg. = negligible = $<10^{-3}$ kg/y)

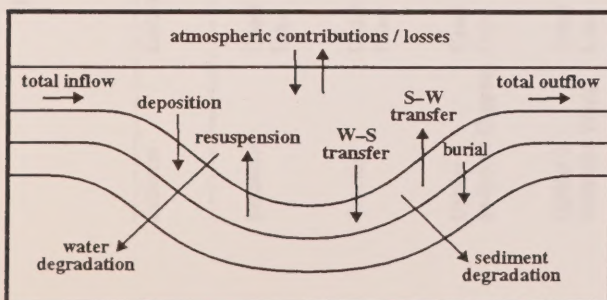
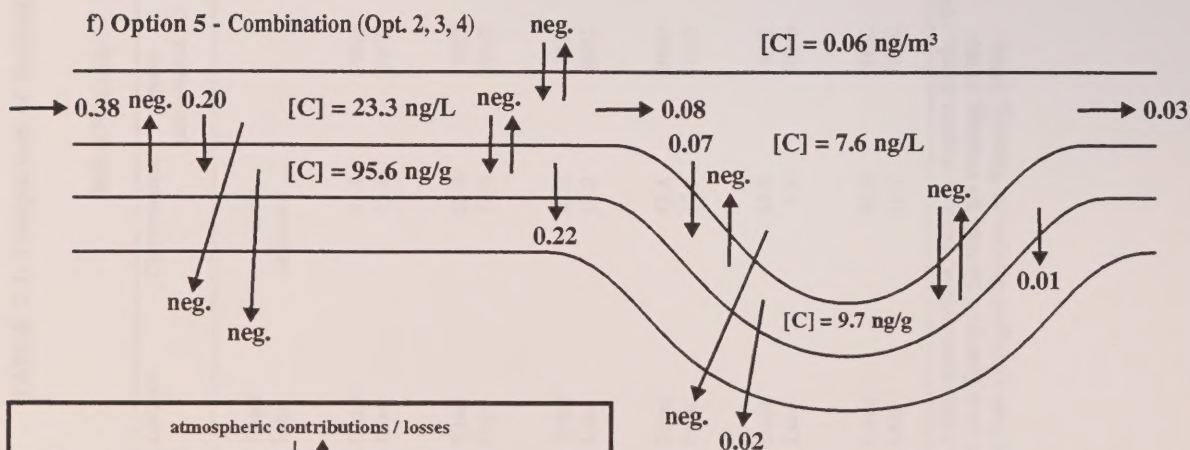
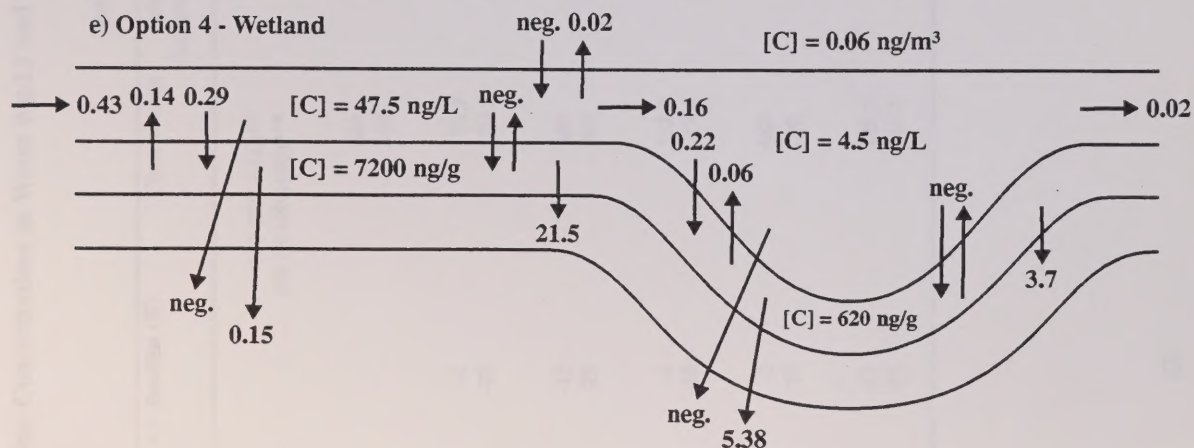
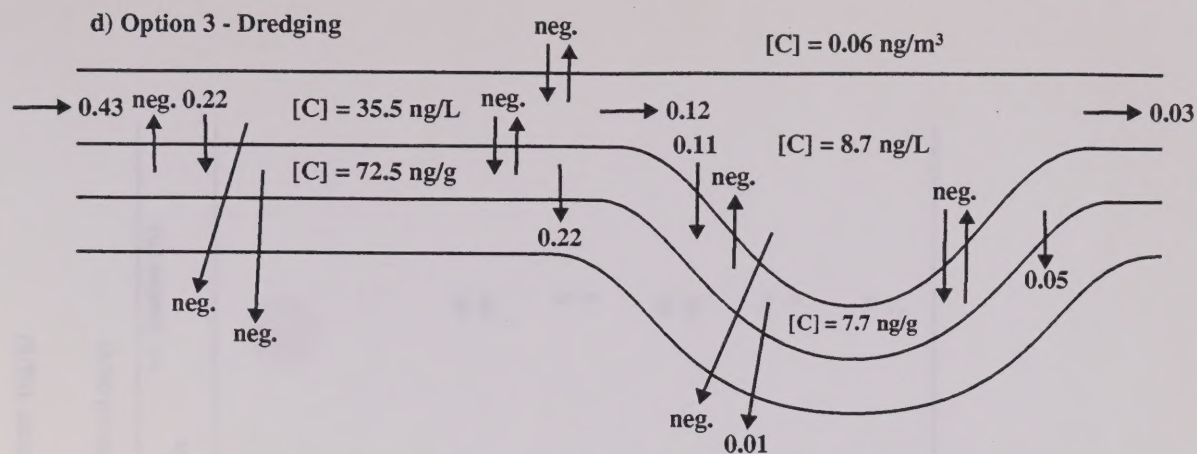


FIGURE 7-2: ...continued

TABLE 7-1: Comparison of Benzo(a)Pyrene Concentrations in Water (ng/L) and Sediment (ng/g)

Scenario	Location	BaP in Water (ng/L)		BaP in Sediment (ng/g)		
		Concentration	Source (inflow/inplace, %)	+/- Baseline (%)	Concentration	Source (inflow/inplace, %)
Measured	Canal Lake	104* unknown	- -	- -	660 (500-1000)** 200 (<100-1000)***	- -
Baseline	Canal Lake	53.8 15.8	98/2 70/30	- -	660 200	13/87 5/95
Option 1 Sediment Capping Lake	Canal	52.6 11.4	100/0 100/0	-2 -28	93.7 20.5	100/0 100/0
Option 2 Sediment Traps	Canal Lake	45.7 11.2	98/2 68/32	-15 -29	660 200	21/79 0/100
Option 3 Dredging	Canal Lake	52.6 11.3	100/0 100/0	-2 -28	102.7 17.6	100/0 100/0
Option 4 Wetland	Canal Lake	53.8 3.8	98/2 100/0	0 -76	660 200	13/87 6/94
Option 5 Combination	Canal Lake	44.8 11.9	100/0 100/0	-17 -25	171.7 45.3	100/0 100/0

* assumed, inflow concentration, based on Aquafor Beech, 1994.

** measured, from Ecological Services for Planning, 1994b.

*** measured, from Ecological Services for Planning, 1994a.

TABLE 7-2: Comparison of Anthracene Concentrations in Water (ng/L) and Sediment (ng/g)

Scenario	Location	Anthracene in Water (ng/L)			Anthracene in Sediment (ng/g)		
		Concentration	Source (inflow/inplace, %)	+/- Baseline (%)	Concentration	Source (inflow/inplace, %)	+/- Baseline (%)
Measured	Canal Lake	137* unknown	- -	- -	7200 (6100-8600)** 620 (200-1800)***	- -	- -
Baseline	Canal Lake	47.5 25.2	75/25 18/92	- -	7200 620	1/99 1/99	- -
Option 1 Sediment Capping Lake	Canal	35.6 8.8	100/0 44/56	-25 -65	72.6 7.8	100/0 100/0	-99 -99
Option 2 Sediment Traps	Canal Lake	32.2 17.6	73/27 0/100	-32 -30	7200 620	1/99 1/99	0 0
Option 3 Dredging	Canal Lake	35.5 8.7	100/0 44/56	-25 -65	72.5 7.6	100/0 100/0	-99 -99
Option 4 Wetland	Canal Lake	47.5 4.5	75/25 50/50	0 -82	7200 620	1/99 2/98	0 0
Option 5 Combination	Canal Lake	23.3 7.6	100/0 17/83	-51 -70	95.6 9.7	100/0 10/90	-99 -98

* assumed, inflow concentration, based on Aquafor Beech, 1994.

** measured, from Ecological Services for Planning, 1994b.

*** measured, from Ecological Services for Planning, 1994a.

TABLE 7-3: BaP Persistence and Amounts in the Canal and Lake

Scenario	Location	Amount in Water (kg)	+/-Baseline (%)	Amount in Sediment (kg)	+/-Baseline (%)	Persistence (y)	+/-Baseline (%)
Baseline	Canal Lake	4.1x10 ⁻⁴ 3.8x10 ⁻³	- -	2.24 8.58	- -	4.6 46	- -
Option 1 sediment Capping	Canal Lake	4.0x10 ⁻⁴ 2.7x10 ⁻³	-2 -27	0.02 0.07	-91 -99	0.42 0.40	-91 -99
Option 2 Sediment Traps	Canal Lake	3.5x10 ⁻⁴ 2.7x10 ⁻³	-15 -29	2.24 8.58	0 0	4.8 55	+4 +18
Option 3 Dredging	Canal Lake	6.31x10 ⁻⁴ 0.01	+54 +53	0.07 0.15	-97 -98	0.14 0.86	-97 -98
Option 4 Wetland	Canal Lake	4.1x10 ⁻⁴ 9.2x10 ⁻⁴	0 -76	2.24 8.58	0 0	4.6 48	0 +4
Option 5 Combination	Canal Lake	5.4x10 ⁻⁴ 0.01	+32 +61	0.12 0.40	-94 -95	0.25 2.6	-95 -94

TABLE 7-4: Anthracene Persistence and Amounts in the Canal and Lake

Scenario	Location	Amount in Water (kg)	+/-Baseline (%)	Amount in Sediment (kg)	+/-Baseline (%)	Persistence (y)	+/-Baseline (%)
Baseline	Canal Lake	3.6x10 ⁻⁴ 0.01	- -	24.5 26.6	- -	57 145	- -
Option 1 Sediment Capping	Canal Lake	2.7x10 ⁻⁴ 2.2x10 ⁻³	-25 -68	0.16 0.03	-99 -99	0.37 0.20	-99 -99
Option 2 Sediment Traps	Canal Lake	2.5x10 ⁻⁴ 4.3x10 ⁻³	-32 -31	24.5 26.6	0 0	65 204	+14 +47
Option 3 Dredging	Canal Lake	4.3x10 ⁻⁴ 4.6x10 ⁻³	+18 -32	0.05 0.07	-99 -99	0.12 0.5	-99 -99
Option 4 Wetland	Canal Lake	3.6x10 ⁻⁴ 1.1x10 ⁻³	0 -82	24.5 26.6	0 0	57 150	0 +4
Option 5 Combination	Canal Lake	2.8x10 ⁻⁴ 3.9x10 ⁻³	-22 -44	0.07 0.08	-99 -99	0.17 0.88	-99 -99

7.1 Chemical Sources and Estimates of Fate Under Baseline Conditions

7.1.1 Canal - Baseline Conditions

According to the pseudo-steady-state model estimates under baseline conditions, water and particulate inflows from Eastward Creek (the only tributary to the canal) and stormsewer discharges (i.e., total landbased flows) represent the largest source of chemical to the water column in the canal, with particulate flows accounting for 96% (0.48 kg/y) of the BaP, and water and particulate inflows accounting for 44% and 31% of the anthracene, respectively (totalling 0.32 kg/y). Chemical loadings resulting from Eastward Creek and stormsewer discharges were assumed to be roughly equal.

The presence of PAHs in stormwater discharged to the canal is typical of any urban area and results from the deposition of particulate-associated PAHs from the atmosphere (primarily due to combustion-related processes) as well as the deposition of petroleum based PAHs onto road and other impervious surfaces and their subsequent transport to the receiving water via stormwater runoff (Baek et al., 1991). In comparison to BaP, anthracene is more volatile and soluble. Hoffman et al. (1984) note that higher molecular weight PAHs, such as BaP, represent a larger percentage of total PAHs in comparison to lower molecular weight PAHs, such as anthracene, in atmospheric and urban runoff PAH distributions. This likely accounts for the much smaller contribution of anthracene to the canal via land based flows, of which a larger percentage is in the dissolved phase, when compared to BaP.

In the canal, resuspension accounts for the majority of remaining chemical contributions to the water column (i.e., 3% of the BaP and 25% of the anthracene). Factors such as shallow water depth, large particulate loadings, remobilization of sediments during storm events, and a deep active sediment layer contribute to sediment resuspension in the canal. Atmospheric deposition, volatilization and sediment-water diffusion are negligible sources of BaP and anthracene to the water column in the canal.

Chemical losses from the canal water column are primarily due to deposition, with particulate outflow accounting for secondary losses of chemical. In the canal, 66% of the BaP and 51% of the anthracene are lost from the water column via deposition, and 33% of the BaP and 26% of the anthracene are lost due to particulate outflows. An additional 23% of the anthracene is lost via water outflow. High deposition rates in the canal are likely the result of high solids loadings, low flow

rate, the long length of the canal, and a low hydraulic profile (Gore & Storrie Limited, 1995a). In fact, the use of the canal as a sediment trap had been considered in order to improve the quality of water discharged from the canal to the lake (Gore & Storrie Limited, 1995a). Contaminants lost from the water column via particle outflows are most likely associated with fine suspended particles to which PAHs are more strongly adsorbed, and which, due to their small size, tend to behave as if they are dissolved (Dempsey et al., 1993). This relationship is reflected in the presence of finer, organic sediments in the lake, in comparison to the coarse, inorganic sediments of the canal (Golder Associates, 1994). In comparison to BaP, a higher percentage of anthracene is lost via water outflow from the canal due to the difference in solubility between the two chemicals. Chemical transformation in water, volatilization and water-sediment diffusion represent insignificant mechanisms for loss of BaP and anthracene from the water column in the canal.

As would be expected, based on the affinity of PAHs for particulates, deposition represents the primary source of BaP (100%) and anthracene (100%) to the canal sediment. Water-sediment diffusion is negligible. Burial represents the primary loss mechanism for chemical from the canal sediment, with over 80% of the BaP and 99% of the anthracene lost in this manner. The large influx of solids due to stormwater discharges, and the rapid settling of the larger solids accounts for the high rates of burial in the canal. Degradation accounts for additional losses of BaP (19%). Sediment-water diffusion and resuspension are insignificant loss mechanisms for chemical from the canal sediments. Refer to Tables 7-1 and 7-2 for a summary of measured sediment and estimated concentrations of BaP and anthracene in the water for baseline conditions, as well as a comparison of estimated water and sediment concentrations associated with each of the remedial scenarios.

7.1.2 Lake - Baseline Conditions

In the lake under baseline conditions, the primary sources of chemical to the water column are particulate inflow from the canal and resuspension of in-place sediment. In the case of BaP, 68% is due to particulate inflow and 29% due to resuspension, whereas, in the case of anthracene resuspension represents the larger contributor to the lake water column at 59%, with particulate inflow representing 39%. The difference in the primary source contributing to the water column between the two chemicals is due to the higher concentration of BaP in the canal water (i.e., 53.8 ng/L of BaP versus 47.5 ng/L of anthracene) and the higher concentration of anthracene in the lake sediments (i.e., 620 ng/g of anthracene versus 200 ng/g of BaP). As indicated above, factors such as the lake's shallow depth, the fine organic nature of the sediments, and relatively deep active sediment

layer, as well as influences from wind, biota and sediment disturbances during storm events, contribute to resuspension of sediments in the lake. Water column contributions via atmospheric deposition, volatilization and sediment-water diffusion are negligible.

Deposition of particulates represents the primary loss mechanism for chemical from the lake water column under baseline conditions, with 66% of the BaP and 51% of the anthracene lost in this manner. Loss of chemical via the outflow represents a significant secondary loss mechanism, with 33% of BaP lost in association with particulates in the outflow, 26% of anthracene discharged in the dissolved form and 23% lost via particulates in the outflow. Correspondingly, 100% of the chemical contribution to the lake sediment is due to deposition. The low solubility, low volatility, and high octanol-water partition coefficients and persistence of BaP and anthracene imply that they will remain associated with particulates, a fact which is reflected in negligible losses via volatilization, water transformation, water-sediment diffusion and sediment-water diffusion. An additional factor contributing to poor water and sediment quality is that as organic sediments degrade, the relative concentration of chemical increases, resulting in a given resuspension rate re-introducing more chemical to the water than a comparable deposition rate will remove (Diamond and Ling-Lamprecht, 1996).

In comparison to the contributions to the lake water column, resuspension represents an insignificant loss mechanism for BaP and anthracene from the lake sediment due to significantly higher rates of burial and sediment transformation. In the case of BaP, over 81% is lost from the lake sediments via burial with an additional 19% lost via degradation. For anthracene, the primary loss mechanism from the lake sediments is via degradation (58%), with burial representing a secondary mechanism (40%). Factors, such as higher concentrations in the sediment, and a lower degradation half life, contribute to a larger portion of the anthracene being lost via degradation, in comparison to BaP. Refer to Tables 7-1 and 7-2 for a summary of measured sediment and estimated concentrations of BaP and anthracene in the water for baseline conditions, as well as a comparison of estimated water and sediment concentrations associated with each of the remedial scenarios.

7.1.3 Chemical Persistence

As indicated on Table 7-3 and 7-4, the persistence of BaP was estimated to be 4.6 years in the canal and 46 years in the lake, and anthracene persistence was estimated to be 57 years in the canal and 145 years in the lake, under pseudo-steady-state conditions. Persistence is calculated as total mass of a chemical divided by total inputs of the chemical, and reflects the time over which chemical concentrations would fall to 37% of their present level if all loadings ceased. Chemical persistence is significantly lower under steady-state conditions, with a BaP persistence of 0.61 and 2.24 years in the canal and lake respectively, and an anthracene persistence of 0.6 and 3.2 years for the canal and lake respectively. The difference between the two situations is due to the presence of significant historical/inplace chemical within the lake and canal sediments, a fact which is not considered by the steady-state model.

Chemical persistence in Mohawk Lake is relatively high, primarily due to the large amount of inplace contaminants, a deep active sediment layer, high particulate loading rates and corresponding rates of burial. There is, however, some uncertainty associated with the model estimates of chemical persistence, as well as contaminant transformation rates in sediment, since these processes are a function of contaminant degradation rates which themselves are uncertain, difficult to determine and site specific (Diamond et al., 1996; Ling et al., 1993; Mackay et al., 1992).

7.1.4 Inflow versus Inplace Contaminant Sources

As demonstrated by a comparison of steady-state and pseudo-steady-state model results, stormwater inflows represent the largest source of contaminants to the canal, and although over 99% of the BaP and anthracene present in the canal are contained within the sediments, the high rates of deposition, burial and transformation, and relatively low rates of resuspension result in the canal sediments representing a sink rather than a source of chemical. Similarly in the lake, historically accumulated sediments present a potentially large source of contaminant to the water column. In the case of BaP, due to high rates of deposition, burial and transformation, and a relatively low rate of resuspension, the lake sediments are a sink rather than a source of BaP. Consequently, current inflows are the largest source of BaP to the lake water column. However, in the case of anthracene, the reverse is true, where due to high concentrations in the sediment, resuspension represents a significant source of contaminant to the lake water column. Figure 7-3 and 7-4 illustrate the distribution of BaP and anthracene in the water column due to inflow and inplace contributions.

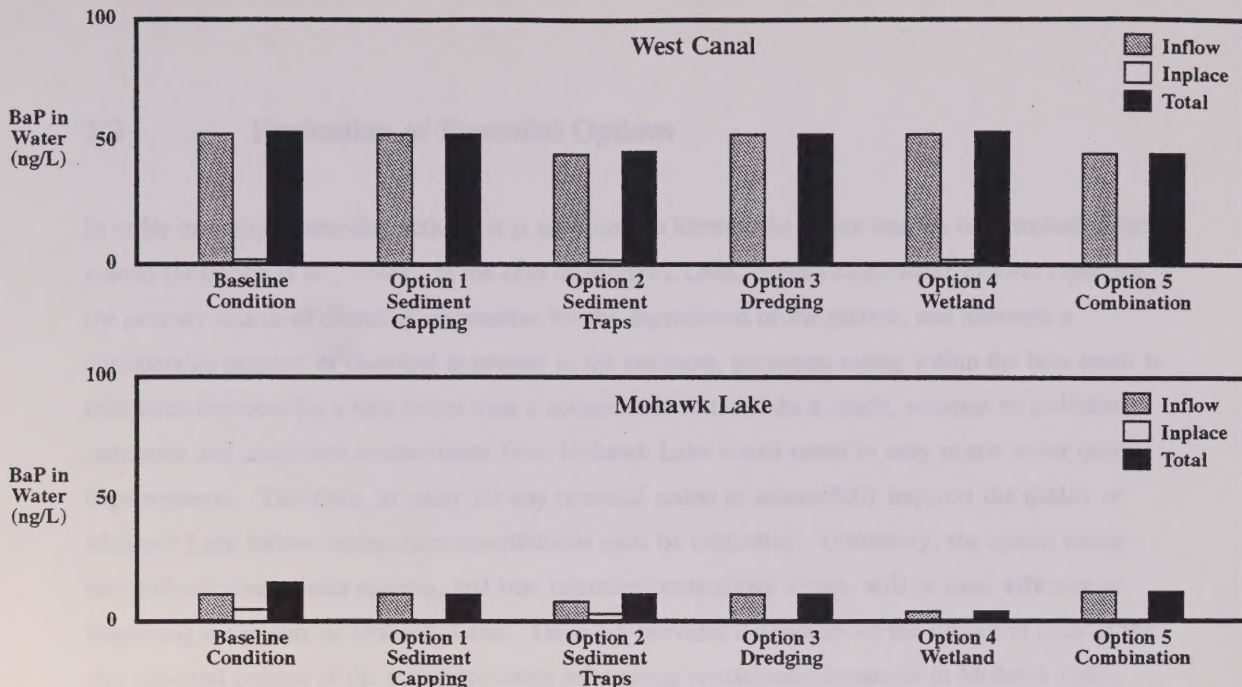


FIGURE 7-3: Contributions of BaP to the Water Column from Inflow and Inplace Sources for Baseline and Remedial Scenarios

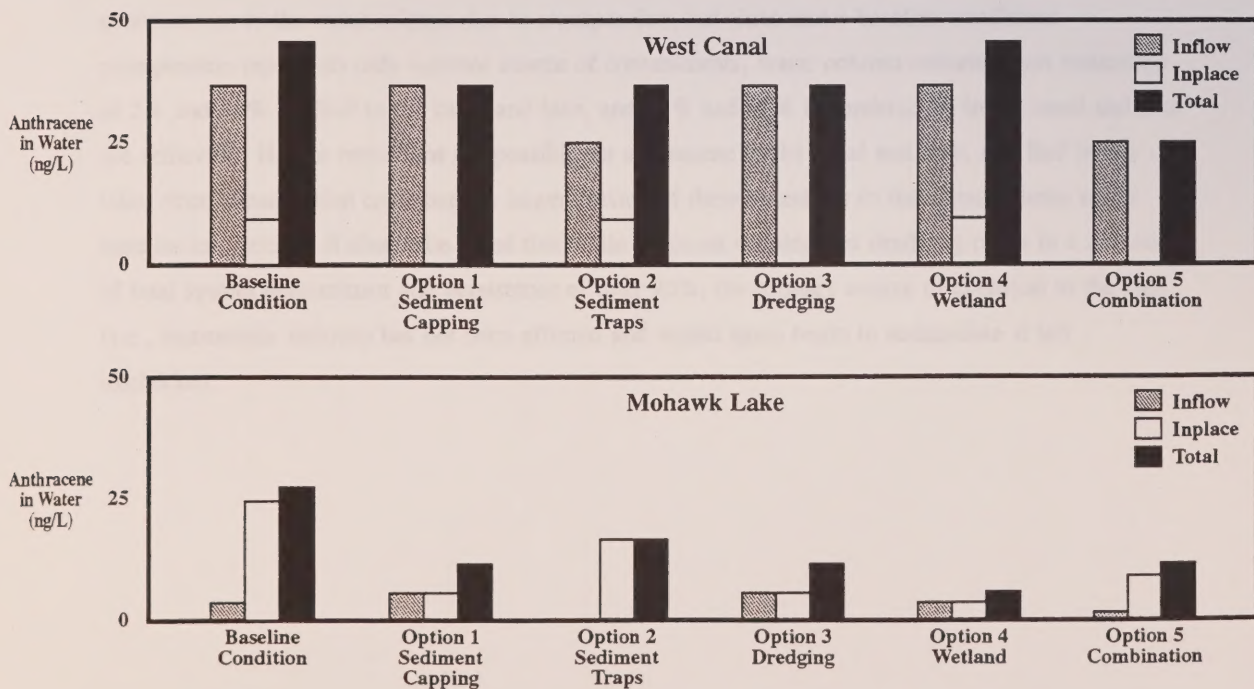


FIGURE 7-4: Contributions of Anthracene to the Water Column from Inflow and Inplace Sources for Baseline and Remedial Scenarios

7.2 Evaluation of Remedial Options

In order to evaluate remedial actions, it is necessary to identify the major sources of chemical to the system (Diamond et al., 1994). In the case of Mohawk Lake, current stormwater inflows represent the primary source of chemical responsible for the degradation of the system, and although a considerable quantity of chemical is present in the sediment, processes acting within the lake result in sediments representing a sink rather than a contaminant source. As a result, removal or isolation of sediments and associated contaminants from Mohawk Lake would result in only minor water quality improvements. Therefore, in order for any remedial action to successfully improve the quality of Mohawk Lake inflow contaminant contributions must be controlled. Ultimately, the option which best reduces contaminant sources, and best increases contaminant losses, will be most effective at improving the quality of Mohawk Lake. Table 7-5 provides a summary of the impact of each of the five remedial options of the major processes influencing contaminant dynamics in Mohawk Lake.

Sediment capping (Option 1) and dredging (Option 3) result in the isolation and removal of sediments and associated historical/inplace contaminants from the system (i.e., >99% of BaP and anthracene removed from the canal and lake). Removal/isolation of sediments effectively eliminates contaminant contributions to the water column due to resuspension, but since under baseline conditions resuspension represents only a minor source of contaminants, water column concentration reductions of 2% and 28% for BaP in the canal and lake, and 25% and 65% for anthracene in the canal and lake are achieved. Higher reductions are possible for anthracene in the canal and lake, and BaP in the lake, since resuspension contributes a larger portion of these chemicals to the water column under baseline conditions. It should be noted that while sediment capping and dredging result in a reduction of total system contaminant and persistence of over 90%, the primary source of chemical to the lake (i.e., stormwater inflows) has not been affected and would again begin to accumulate if left unchecked.

TABLE 7-5: Comparison of Remedial Options

	Baseline Primary Processes	Option 1 Sediment Capping	Option 2 Sediment Traps	Option 3 Dredging	Option 4 Wetland	Option 5 Combination
Canal-Water Column	Sources:	0%	-8%	0%	0%	-8%
	Losses:	-3%	+19%	-3%	0%	+16%
	Particulate Outflow	-2%	-49%	-2%	0%	-50%
Lake-Water Column	Sources:	-2%	-22%	-2%	-13%	0%
	Resuspension	0%	0%	-29%	-75%	-44%
	Losses:	-30%	+2%	-31%	-9%	-49%
	Particulate Outflow	-28%	-57%	-28%	-76%	-25%

Remedial Options 2 (sediment traps) and 3 (wetland) were proven to be moderately effective in reducing contaminant contributions from inflow sources. Sediment traps result in a BaP concentration reduction in canal and lake water of 15% and 29% due to particulate inflow reduction of 8% and 22% respectively, and an anthracene concentration reduction in canal and lake water of 32% and 30% due to particulate inflow reductions of 63% and 38% respectively. Wetland construction resulted in a BaP concentration reductions in the lake water of 76% due to resuspension and particulate inflow reductions of 78% and 10%, and an anthracene concentration reduction in the lake water of 82% due to resuspension and particulate inflow reductions of 75% and 13%. There was no impact on the concentration of contaminants in sediment and, as a result, resuspension continues to contribute 3% and 33% of BaP to the canal and lake respectively, and 27% and 68% of the anthracene to the canal and lake. Chemical persistence in the canal and lake under the sediment capping scenario, and in the lake under the wetland scenario, increases from 4% to 47% when compared with baseline conditions. This is the result of reductions to particulate outflow (ranging from 49 to 76% in comparison to baseline conditions) and a corresponding increase in deposition (ranging upwards of 19%).

Option 5, a combination of sediment traps, wetland construction and dredging, provides the most significant improvements to overall quality of Mohawk Lake in comparison to baseline conditions when both water and sediment quality improvements are considered. Concentration reductions of 17% and 25% for BaP in the canal and lake, and reduction of 51% and 70% for anthracene in the canal and lake are achieved. These reductions are achieved through the elimination of historical/inplace contaminants, reductions to resuspension, particulate inflows, particulate outflows, and increases in deposition. It should be noted that as a result of these process changes, the contribution of non-particulate associated contaminants in water inflows has increased significantly (ranging from 23% to 643%).

7.3 Selection of the Preferred Remedial Option

As indicated above, the remedial option which best controls the primary processes contributing to contaminants in a system will result in the most significant quality improvements. In the case of Mohawk Lake, since the primary contaminant contributions are associated with stormwater inflows, those remedial options which best control stormwater contaminants will have the most significant influence on the quality of Mohawk Lake.

Of the five options evaluated, Option 5 (combination of sediment traps, wetland and dredging)

provided the best improvements to the overall quality of Mohawk Lake, while the wetland scenario was able to provide the most significant improvement to lake water quality. Of the remaining three options, sediment capping, sediment traps and sediment dredging, no one option was found to be significantly better than the others at improving water quality in Mohawk Lake. This is the result of each of these options addressing contaminant contribution processes individually, rather than in combination (such as Option 5), and since each of these options have limits in their ability to control contaminant contributions.

It must be stressed that the remedial options evaluated for Mohawk Lake which address stormwater inflows are passive, structural, control devices which are designed to remove pollutants prior to their discharge into the lake (i.e., end of pipe treatment). It is expected that significantly better improvements to the quality of Mohawk Lake would be achieved through the implementation of a stormwater management program which includes both stormwater treatment/end of pipe controls and source control techniques which attempt to control the pollutant directly at the point of generation (i.e., public education, industrial spill prevention and housekeeping programs, sewer rehabilitation, erosion control, improved street sweeping, etc). Additionally, it should be noted, that the model developed for Mohawk Lake assumes steady-state conditions, and therefore does not consider the eventual re-accumulation of contaminants in the system as a result of inflow contributions. Consequently, source control becomes even more significant in the protection of the Lake.

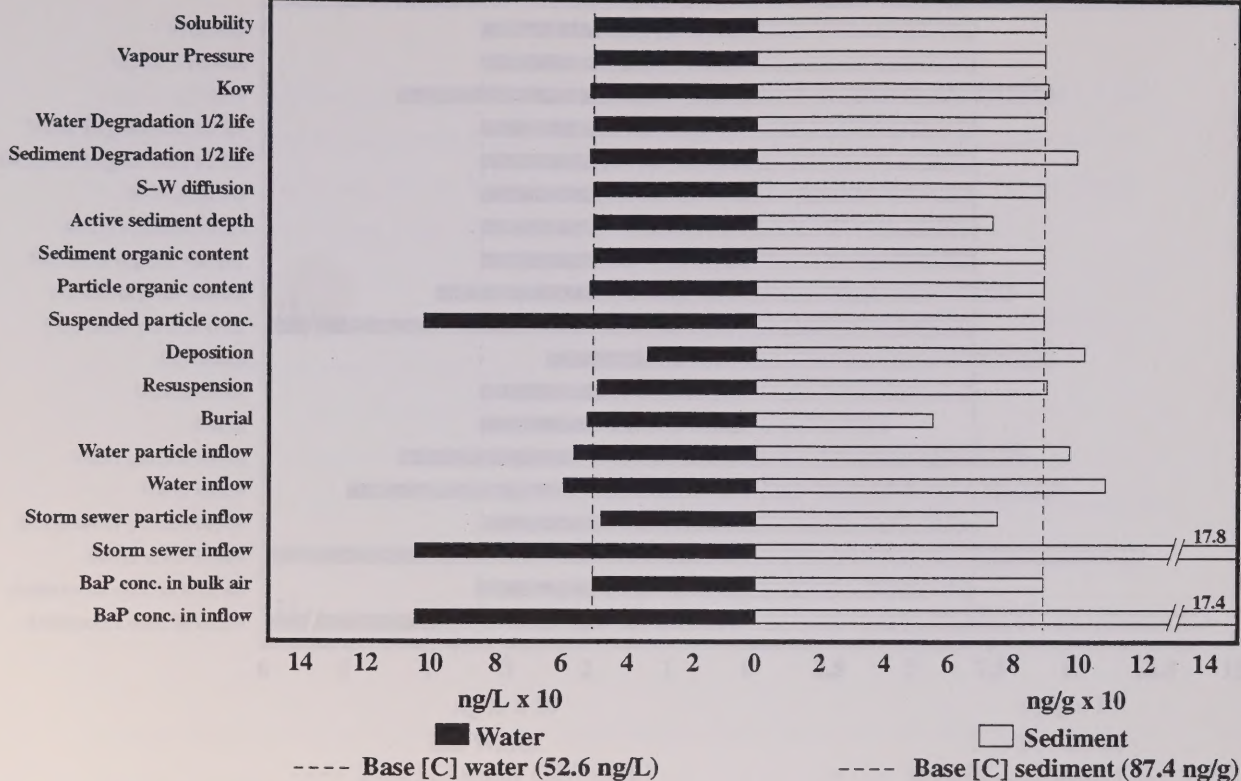
One additional significant factor that must be addressed prior to selecting a remedial option is the objective of the remedial program. For example, in the case of Mohawk Lake, if it is the sole objective to improve the quality of water discharged from the Lake to the Grand River, then the control of contaminants associated with stormwater inflows would likely be adequate. However, if the objective is to improve ecological diversity and aquatic habitat, additional consideration would be required in order to assess the impact of historical/inplace contaminants on aquatic biota, and whether or not sediment removal would be required in order to provide habitat improvements. Additionally, application of remedial options in order to meet dual objectives, such as stormwater treatment and improved aquatic habitat, must be seriously assessed, since as in the case of constructed wetlands, the contaminants trapped by the wetland are detrimental to the aquatic community, and as a results, the two goals are incompatible (Helfield and Diamond, in press).

The use of models to assist in the interpretation of system behaviour and hence guide in the selection of remedial action depends on how well the model simulates observed behaviour (Diamond, 1995). Consequently, the data to which the model output is most sensitive should be as representative of actual conditions as possible. Consequently, a sensitivity analysis was performed on the Mohawk Lake QWASI model in order to identify those model inputs upon which model outputs are most dependant. The sensitivity analysis was performed by doubling selected model parameters one at a time and observing the resulting change in water and sediment concentrations. The results of this sensitivity analysis are illustrated in Figures 8-1 and 8-2.

The results of the sensitivity analysis indicate that the water concentration predicted by the model is most sensitive to input values for water and particulate inflow rates, suspended particle concentration, contaminant inflow concentration, and deposition rates. The sediment concentration predicted by the model is most sensitive to the rates of water inflow and deposition, and inflow contaminant concentration.

In the case of the Mohawk Lake mass balance model, many of the factors to which the model outputs are most sensitive correspond to data inputs which are unknown and/or estimated. The reliability of the model would therefore be greatly improved if research were undertaken to better define these values, in particular, particulate loadings, chemical concentrations in the inflow and water column, and rates of deposition, resuspension, and burial. Additional research into the impact of each remedial option on the above parameters, as well as changes in model inputs reflective of each remedial option, is also required to improve the reliability of the model results. The identification and evaluation of additional remedial options and various combinations of options should also be considered in an attempt to identify one option or one combination of options that can provide significant, not just moderate, improvements to the quality of Mohawk Lake. The assessment of other contaminants of concern in the lake, such as lead and copper, would also be required in order to ensure the remedial options selected, based on the assessment of BaP and anthracene, are as effective at controlling other contaminants of concern.

West Canal



Mohawk Lake

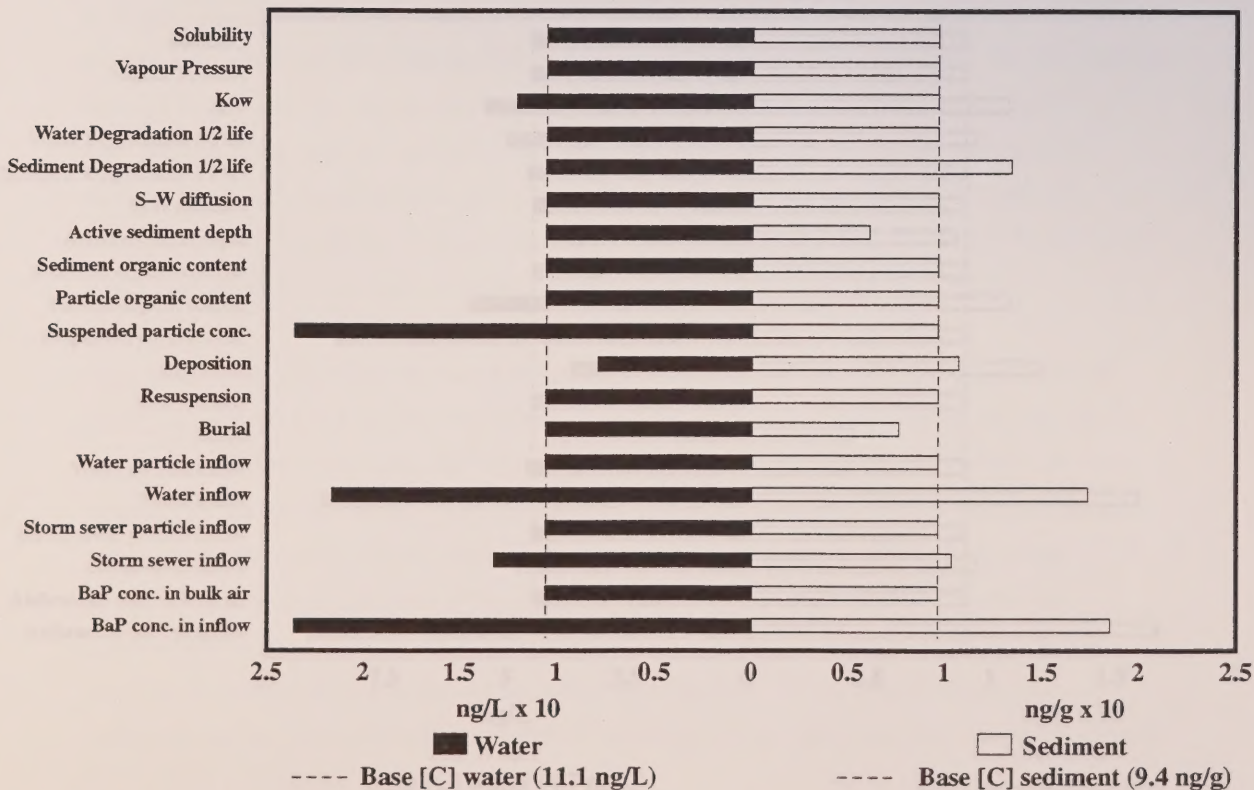


Figure 8-1: Sensitivity of Water and Sediment BaP Concentrations to Doubling Model Parameters

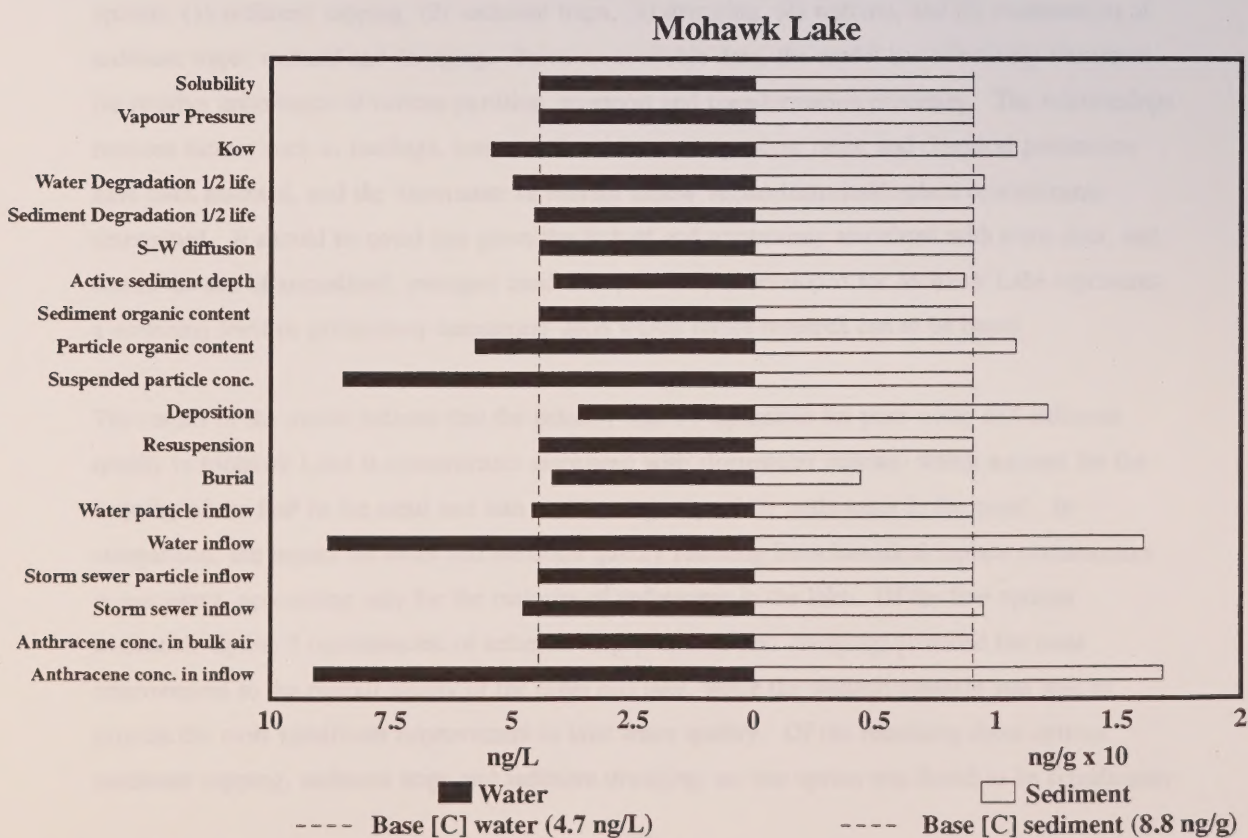
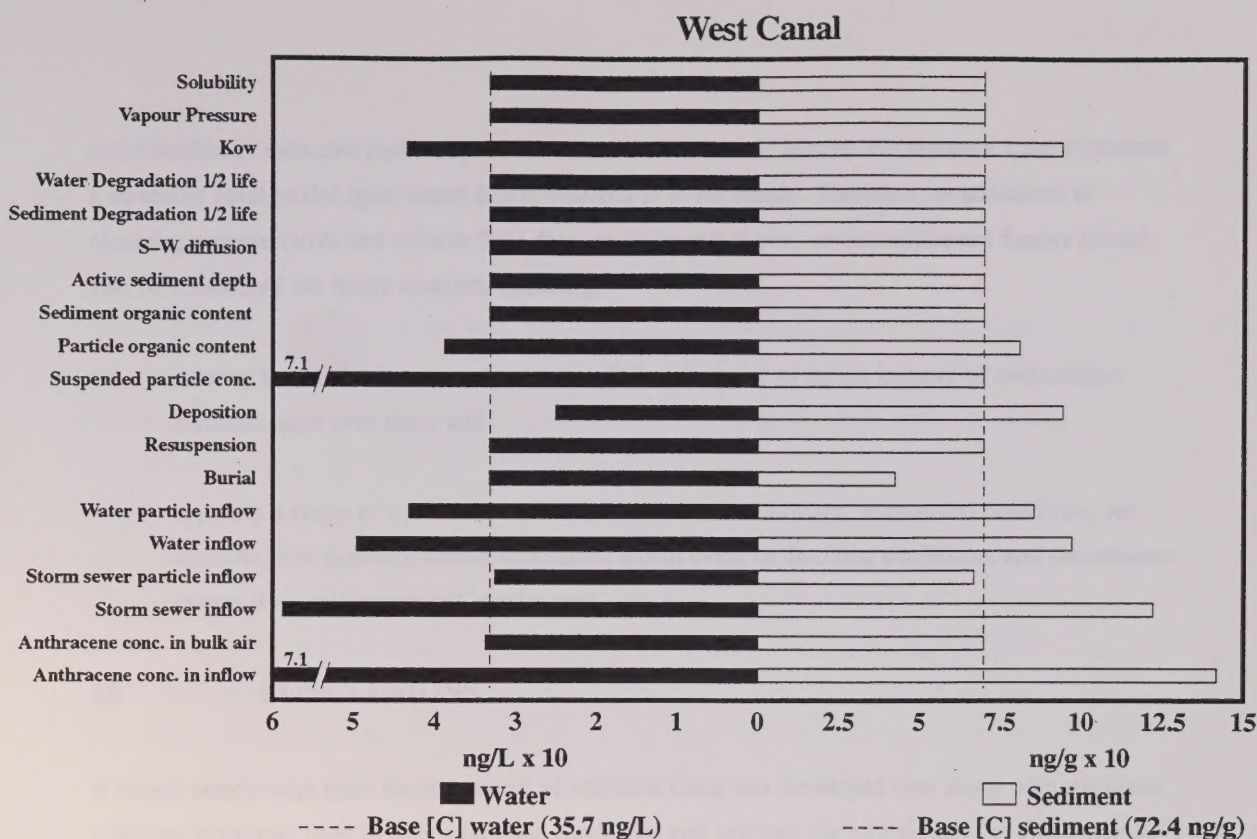


Figure 8-2: Sensitivity of Water and Sediment Anthracene Concentrations to Doubling Model Parameters

Additionally, as indicated previously, the mass balance model developed for Mohawk Lake represents a screening level model upon which future research is to be based. Therefore, in addition to obtaining representative and reliable field data, as discussed above, several additional factors should also be considered for future research including:

- running the model for unsteady-state conditions in order to assess impacts of contaminant accumulations over time, and
- applying a range of conditions to the model rather than average, annualized conditions; for example, low flow/dry season conditions, storm event or flooding conditions, and contaminant ranges (i.e., minimums and maximums).

10 CONCLUSIONS

A simple steady-state mass balance model of Mohawk Lake was developed and, along with the linear additivity principle, used to define baseline conditions and evaluate the effectiveness of five remedial options: (1) sediment capping, (2) sediment traps, (3) dredging, (4) wetland, and (5) combination of sediment traps, wetland and dredging. Based on available data, the model has effectively illustrated the relative importance of various partition, transport and transformation processes. The relationships between factors such as loadings, concentrations, amounts, process rates, and chemical persistence have been assessed, and the importance of current inflow versus historical/inplace contaminants determined. It should be noted that given the lack of and uncertainty associated with some data, and due to the use of annualized, averaged conditions, the model developed for Mohawk Lake represents a screening level or preliminary assessment upon which future research can to be based.

The results of the model indicate that the primary factor responsible for poor water and sediment quality in Mohawk Lake is contaminants associated with stormwater inflows, which account for the majority of the BaP in the canal and lake and the majority of the anthracene in the canal. In comparison, the impact on water and sediment quality resulting from historical/inplace contaminants is secondary, accounting only for the majority of anthracene in the lake. Of the five options evaluated, Option 5 (combination of sediment traps, wetland and dredging) provided the most improvement to the overall quality of the canal and lake, while the wetland scenario was able to provide the most significant improvement to lake water quality. Of the remaining three options (sediment capping, sediment traps and sediment dredging) no one option was found to be significantly

better than the others at improving water quality in Mohawk Lake, and of all the options evaluated, none were found to be the ultimate solution to the environmental problems associated with Mohawk Lake.

Selection of the preferred remedial option must always consider the objective of the remedial program since while stormwater management programs alone will improve water quality, they do not address historical/inplace contaminants and the impact of these contaminants on the health of aquatic organisms present in the Lake.

The quality of Mohawk Lake is perceived by many to be the result of Brantford's industrial past. The results of this study have shown that the environmental condition of the Lake is the result of present day stormwater discharges, typical of most urban areas, and not the result of historical contamination. Comparison of the environmental conditions of Mohawk Lake with that of urban stormwater retention ponds (Marsalek, 1995) suggests that Mohawk Lake acts as a large stormwater treatment facility, essentially protecting the Grand River from the impact of Brantford's stormwater runoff. Through the control of stormwater discharges, moderate improvements to the quality of Mohawk Lake can be achieved, while significant improvements are possible through the implementation of a stormwater management program which includes both treatment of stormwater and source control techniques.

- Aquafor Beech Ltd. 1994. **Draft Metropolitan Toronto Waterfront Wet Weather Outfall Study - Phase II, City of Toronto.**
- Baek, S.O., R.A. Field, M.E. Goldstone, P.W. Kirk, J.N. Lester and R. Perry. 1991. A review of atmospheric polycyclic aromatic hydrocarbons: sources, fate and behaviour. **Water, Air and Soil Poll.**, Vol.60, pp.279-300.
- Barcia, J. 1992. Sustainable management of urban lakes: a new environmental challenge. **Wat. Poll. Res. J. Canada**, Vol.27, No.2, pp.211-219.
- Dempsey, B.A., V.L. Tai, and S.G. Harrison. 1993. Mobilization and removal of contaminants associated with urban dust and dirt. **Wat. Sci. Tech.**, Vol.28, No.3-5, pp.225-230.
- Diamond, M. and H.W. Ling-Lamprecht. 1996. Loadings, dynamics and response time of seven metals in Hamilton Harbour: results of a mass balance study. **Water Qual. Res. J. Canada**, Vol.31., No.3, pp.623-641.
- Diamond, M.L., D. Mackay, D.J. Poulton and F.A. Stride. 1996. Assessing chemical behaviour and developing remedial action using a mass balance model of chemical fate in the Bay of Quinte. **Wat. Res.**, Vol.30, No.2, pp.405-421.
- Diamond, M. 1995. Application of a mass balance model to assess in-place arsenic pollution. **Environ. Sci. Technol.**, Vol. 28, pp.29-42.
- Diamond, M., D. Mackay, D. Poulton, and F. Stride. 1994. Development of a mass balance model of the fate of 17 chemicals in the Bay of Quinte. **J. Great Lakes Res.**, Vol.20, No.4, pp.643-666.
- Ecological Services for Planning Limited. 1994a. **Mohawk Lake (Brantford) Sediment and Water Quality Investigation.**
- Ecological Services for Planning Limited. 1994b. **Sediment Quality and Water Bacteriological Study of Mohawk Lake and Mohawk Canal - Interim Report.**
- Ellis, J.B. 1988. The quality of Urban Discharges. In **Urban Discharges and Receiving Water Quality Impacts, Proceedings of the IAWPRC/IAHR Sub-Committee for Urban Runoff Quality Data, IAWPRC 14th Biennial Conference, Brighton, U.K.**, ed. J.B. Ellis, Pergamon Press, Oxford.
- Environment Canada and Health Canada. 1994. **Canadian Environmental Protection Act - Priority Substances List Assessment Report: Polycyclic Aromatic Hydrocarbons.** Ministry of Supply and Services Canada, National Printers (Ottawa) Inc.
- Golder Associates Ltd. 1994. **Preliminary Geotechnical Investigation - Lake Bed Conditions, Mohawk Lake Rehabilitation, Brantford, Ontario.**
- Gore & Storrie Limited. 1995a. **Mohawk Lake Rehabilitation Project - Stormwater Management Study.**

Gore & Storrie Limited. 1995b. **Mohawk Lake Rehabilitation Project - Ecological Features of Mohawk Lake.**

Gore & Storrie Limited. 1995b. **In-Situ Treatment of Lakebed Sediment - A Review of Treatment/Stabilization Technologies.**

Helfield, J.M. and M.L. Diamond. 1996. Use of constructed wetlands for urban stream restoration: a critical analysis. **Environmental Management**, in press.

Hoffman, E.J., G.L. Mills, J.S. Latimer and G. Quinn. 1984. Urban runoff as a source of polynuclear aromatic hydrocarbons to coastal waters. **Environ. Sci. Technol.**, Vol.18, No.8, pp.580-587.

Kayal, S.I. and D.W. Connel. 1989. Polycyclic aromatic hydrocarbons (PAHs) in sediment of the Brisbane River (Australia) - preliminary results. **Wat. Sci. Tech.**, Vol.21, No.2, pp.161-165.

Ling, H., M. Diamond and D. Mackay. 1993. Application of the QWASI fugacity/aquivalence model to assessing sources and fate of contaminants in Hamilton Harbour. **J.Great Lakes Res.**, Vol.19, No.3, pp.582-602.

Mackay, D., Wan Ying Sui, and Kuo Ching Ma. 1992. **Illustrated Handbook of Physical-Chemical Properties and Environmental Fate of Organic Chemicals.** Lewis Publishers, Chelsea, Michigan.

Mackay, D. 1991. **Multimedia Environmental Models: The Fugacity Approach.** Lewis Publishers, Chelsea, Michigan.

Mackay, D. and M. Diamond. 1989. Application of the QWASI (Quantitative Air Water Sediment Interaction) Fugacity Model to the dynamics of organic and inorganic chemicals in lakes. **Chemosphere**, Vol.18, No.7-8, pp.1343-1365.

Mackay, D., M. Joy, and S. Paterson. 1983. A Quantitative Water, Air, Sediment Interaction (QWASI) fugacity model for describing the fate of chemicals in lakes. **Chemosphere**, Vol.12, No.7/8, pp.981-997.

Marsalek, J. 1995. **Stormwater Pond Sediments: Characteristics, Removal and Disposal.** Presented at Metropolitan Toronto and Region Conservation Authority Stormwater Management, Monitoring and Maintenance Seminar, May 1995, Toronto, Ontario.

Mayer, T. and E. Nagy. 1992. Polycyclic aromatic hydrocarbons in suspended particulates from Hamilton Harbour. **Water Poll. Res. J. Canada**, Vol.27, No.4, pp.807-831.

McVeety, B.D. and R.A. Hites. 1988. Atmospheric deposition of polycyclic aromatic hydrocarbons to water surfaces: a mass balance approach. **Atmos. Environ.**, Vol.22, No.3, pp.511-536.

M.M. Dillon. 1972. **Mohawk Lake Study, Brantford, Ontario.** Prepared for Grand River Conservation Authority.

Murray, J. 1988. Nonpoint pollution first step in control. In **Design of Urban Runoff Quality Controls, Proceedings of an Engineering Foundation Conference on Current Practice and Design**

Criteria for Urban Quality Control, Potosi, Missouri, July 1988, ed. L.A. Roesner, B. Urbonas and M.B. Sonnen. American Society of Civil Engineers, New York, New York.

Peterson, S.A. 1994. **Dredging and Lake Restoration**. Corvallis Environmental Research Laboratory, U.S. EPA, Corvallis, Oregon.

Pitt, R., M. Lalor, R. Field and M. Brown. 1993. The investigation of source are controls for the treatment of urban stormwater toxicants. **Wat.Sci. Tech.**, Vol.28, No. 3-5, pp.271-282.

Striver, W. and D. Mackay. 1990. The Linear Additivity Principle in environmental modelling: application to chemical behaviour in soil. **Chemosphere**, Vol.19, No.8-9, pp.1187-1198.

Urbonas, B. 1994. Assessment of stormwater BMP's and their technology. **Wat. Sci. Tech.**, Vol.29, No.1-2, pp.347-353.

U.S. EPA. 1983. **Results of the Nationwide Urban Runoff Program**. Water Planning Division, PB-84-185552, Washington, D.C.

Vigon, B. 1985. The status of nonpoint source pollution: its nature, extent and control. **Water Resources Bulletin**, Vol.21, No.2, pp.179-184.

TABLE A-1: Comparison of Kinetic/Physical Process Rates
for Benthic and Suspended Sediment

Location	Location	Process/Parameter	Value (1/d)	Value (1/d)	Location	Location	Process/Parameter	Value (1/d)	Value (1/d)
Station 1	Canal	Resuspension	0.01 (0.01)		Station 2	Canal	Resuspension	0.01 (0.01)	
		Deposition	0.01 (0.01)				Resuspension	0.01 (0.01)	
		Settling	0.01 (0.01)				Settling	0.01 (0.01)	
	Lake	Resuspension	0.01 (0.01)			Lake	Resuspension	0.01 (0.01)	
		Deposition	0.01 (0.01)				Deposition	0.01 (0.01)	
		Settling	0.01 (0.01)				Settling	0.01 (0.01)	
Station 3	Canal	Resuspension	0.01 (0.01)		Station 4	Canal	Resuspension	0.01 (0.01)	
		Deposition	0.01 (0.01)				Resuspension	0.01 (0.01)	
		Settling	0.01 (0.01)				Settling	0.01 (0.01)	
	Lake	Resuspension	0.01 (0.01)			Lake	Resuspension	0.01 (0.01)	
		Deposition	0.01 (0.01)				Deposition	0.01 (0.01)	
		Settling	0.01 (0.01)				Settling	0.01 (0.01)	
Station 5	Canal	Resuspension	0.01 (0.01)		Station 6	Canal	Resuspension	0.01 (0.01)	
		Deposition	0.01 (0.01)				Resuspension	0.01 (0.01)	
		Settling	0.01 (0.01)				Settling	0.01 (0.01)	
	Lake	Resuspension	0.01 (0.01)			Lake	Resuspension	0.01 (0.01)	
		Deposition	0.01 (0.01)				Deposition	0.01 (0.01)	
		Settling	0.01 (0.01)				Settling	0.01 (0.01)	
Station 7	Canal	Resuspension	0.01 (0.01)		Station 8	Canal	Resuspension	0.01 (0.01)	
		Deposition	0.01 (0.01)				Resuspension	0.01 (0.01)	
		Settling	0.01 (0.01)				Settling	0.01 (0.01)	
	Lake	Resuspension	0.01 (0.01)			Lake	Resuspension	0.01 (0.01)	
		Deposition	0.01 (0.01)				Deposition	0.01 (0.01)	
		Settling	0.01 (0.01)				Settling	0.01 (0.01)	

APPENDIX A

SUMMARY OF PROCESS RATES AFFECTING BAP AND ANTHRACENE DYNAMICS IN THE CANAL AND LAKE

**TABLE A-1: Comparison of Benzo(a)Pyrene Process Rates
for Baseline and Remedial Scenarios**

Scenario	Location	Contributions to Water (kg/y) +/- Baseline (%)			Losses from Water (kg/y) +/- Baseline (%)		
Baseline	Canal	Particulate inflow	0.48 (96%)	-	Deposition	0.33 (66%)	-
		Resuspension	0.01 (3%)	-	Particulate outflow	0.17 (33%)	-
		Total	0.50	-	Total	0.50	-
	Lake	Resuspension	0.08 (29%)	-	Deposition	0.20 (76%)	-
		Particulate inflow	0.18 (68%)	-	Particulate Outflow	0.06 (22%)	-
		Total	0.26	-	Total	0.26	-
Option 1 Sediment Capping	Canal	Particulate inflow	0.48 (97%)	0	Deposition	0.32 (66%)	-3
		Total	0.49	-2	Particulate outflow	0.16 (34%)	-2
					Total	0.49	-2
	Lake				Deposition	0.14 (76%)	-30
		Particulate inflow	0.17 (94%)	-2	Particulate Outflow	0.04 (23%)	-28
		Total	0.19	-29	Total	0.19	-29
Option 2 Sediment Traps	Canal	Particulate inflow	0.44 (91%)	-8	Deposition	0.39 (82%)	+19
		Resuspension	0.01 (3%)	0	Particulate outflow	0.09 (18%)	-49
		Total	0.48	-3	Total	0.48	- 3
	Lake	Resuspension	0.08 (33%)	0	Deposition	0.2 (88%)	+2
		Particulate inflow	0.14 (60%)	-22	Particulate Outflow	0.02 (11%)	-57
		Total	0.23	-11	Total	0.23	-11
Option 3 Dredging	Canal	Particulate inflow	0.48 (98%)	0	Deposition	0.32 (66%)	-3
		Total	0.49	-2	Particulate outflow	0.16 (34%)	-2
					Total	0.49	-2
	Lake	Particulate inflow	0.17 (94%)	-2	Deposition	0.14 (75%)	-31
		Total	0.18	-29	Particulate Outflow	0.04 (23%)	-28
					Total	0.18	-29
Option 4 Wetland	Canal	Particulate inflow	0.48 (66%)	0	Deposition	0.33 (66%)	0
		Resuspension	0.01 (3%)	0	Particulate outflow	0.17 (33%)	0
		Total	0.05	0	Total	0.5	0
	Lake	Resuspension	0.02 (10%)	-75	Deposition	0.18 (92%)	-9
		Particulate inflow	0.15 (78%)	-13	Particulate Outflow	0.01 (7%)	-76
		Total	0.20	-24	Total	0.2	-24
Option 5 Combination	Canal	Particulate inflow	0.44 (94%)	-8	Deposition	0.38 (82%)	+16
		Total	0.47	-6	Particulate outflow	0.08 (18%)	-50
					Total	0.47	-6
	Lake	Particulate inflow	0.10 (65%)	-44	Deposition	0.10 (66%)	-49
		Water inflow	0.05 (34%)	+643	Particulate Outflow	0.04 (29%)	-25
		Total	0.15	-41	Total	0.15	-41

**TABLE A-1 con't: Comparison of Benzo(a)Pyrene Process Rates
for Baseline Conditions and Remedial Scenarios**

Scenario	Location		Contributions to Sediment (kg/y)	+/- Baseline (%)		Losses from Sediment (kg/y)	+/- Baseline (%)
Baseline	Canal	Deposition	0.33 (100%)	-	Burial	1.97 (81%)	-
		Total	0.33	-	Degradation	0.45 (19%)	-
					Total	2.44	-
	Lake	Deposition	0.20 (100%)	-	Degradation	1.74 (58%)	-
		Total	0.20	-	Burial	1.19 (40%)	-
					Total	3.01	-
Option 1 Sediment Capping	Canal	Deposition	0.32 (100%)	-3	Burial	0.28 (87%)	-86
		Total	0.32	-3	Degradation	0.04 (13%)	-91
					Total	0.32	-87
	Lake	Deposition	0.14 (100%)	-3	Degradation	0.01 (10%)	-99
		Total	0.14	-3	Burial	0.12 (87%)	-90
					Total	0.14	-95
Option 2 Sediment Traps	Canal	Deposition	0.39 (100%)	+19	Burial	1.38 (75%)	-30
		Total	0.39	+19	Degradation	0.45 (25%)	0
					Total	1.85	-24
	Lake	Deposition	0.23 (100%)	-79	Degradation	1.74 (66%)	0
		Total	0.23	-79	Burial	0.83 (32%)	-30
					Total	2.65	-12
Option 3 Dredging	Canal	Deposition	0.32 (100%)	-3	Burial	0.31 (95%)	-84
		Total	0.32	-3	Degradation	0.01 (4%)	-97
					Total	0.32	-87
	Lake	Deposition	0.14 (100%)	-31	Degradation	0.03 (22%)	-98
		Total	0.14	-31	Burial	0.10 (76%)	-91
					Total	0.14	-95
Option 4 Wetland	Canal	Deposition	0.33 (100%)	0	Burial	1.97 (81%)	0
		Total	0.33	0	Degradation	0.45 (19%)	0
					Total	2.44	0
	Lake	Deposition	0.23 (100%)	-9	Degradation	1.74 (59%)	0
		Total	0.23	-9	Burial	1.19 (40%)	0
					Total	2.95	-2
Option 5 Combination	Canal	Deposition	0.38 (100%)	+16	Burial	0.36 (93%)	-82
		Total	0.38	+16	Degradation	0.02 (6%)	-9
					Total	0.38	-84
	Lake	Deposition	0.10 (100%)	-49	Degradation	0.08 (62%)	-95
		Total	0.10	-49	Burial	0.05 (37%)	-96
					Total	0.13	-96

**TABLE A-2: Comparison of Anthracene Process Rates
for Baseline Conditions and Remedial Scenarios**

Scenario	Location	Contributions to Water (kg/y) +/- Baseline (%)			Losses from Water (kg/y) +/- Baseline (%)			
Baseline	Canal	Particulate inflow	0.18 (31%)	-	Deposition	0.29 (51%)	-	
		Resuspension	0.14 (25%)	-	Particulate outflow	0.15 (26%)	-	
		Inflow	0.26 (44%)	-	Outflow	0.13 (23%)	-	
		Total	0.58	-	Total	0.58	-	
	Lake	Resuspension	0.24 (59%)	-	Deposition	0.31 (76%)	-	
		Particulate inflow	0.16 (39%)	-	Particulate Outflow	0.09 (22%)	-	
		Total	0.40	-	Total	0.40	-	
Option 1 Sediment Capping	Canal	Particulate inflow	0.18 (41%)	0	Deposition	0.22 (51%)	-25	
		Inflow	0.26 (59%)	0	Particulate outflow	0.11 (26%)	-25	
		Total	0.43	-25	Outflow	0.10 (23%)	-25	
					Total	0.43	-25	
	Lake	Particulate inflow	0.12 (94%)	-25	Deposition	0.10 (76%)	-69	
		Total	0.13	-69	Particulate Outflow	0.03 (23%)	-68	
					Total	0.13	-69	
Option 2 Sediment Traps	Canal	Particulate inflow	0.07 (12%)	-63	Deposition	0.28 (53%)	-5	
		Resuspension	0.14 (27%)	0	Particulate outflow	0.06 (11%)	-59	
		Inflow	0.32 (30%)	+23	Outflow	0.18 (34%)	+36	
		Total	0.53	-9	Total	0.52	-9	
	Lake	Resuspension	0.24 (68%)	0	Deposition	0.31 (88%)	0	
		Particulate inflow	0.10 (28%)	-38	Particulate Outflow	0.04 (11%)	-58	
		Total	0.35	-13	Total	0.35	-13	
Option 3 Dredging	Canal	Particulate inflow	0.18 (41%)	0	Deposition	0.22 (50%)	-26	
		Inflow	0.26 (59%)	0	Particulate outflow	0.11 (26%)	-25	
		Total	0.43	-25	Outflow	0.10 (23%)	-23	
					Total	0.43	-25	
	Lake	Particulate inflow	0.12 (94%)	-25	Deposition	0.09 (75%)	-69	
		Total	0.13	-69	Particulate Outflow	0.03 (23%)	-68	
					Total	0.13	-69	
Option 4 Wetland	Canal	Particulate inflow	0.18 (31%)	0	Deposition	0.29 (51%)	0	
		Resuspension	0.14 (25%)	0	Particulate outflow	0.15 (26%)	0	
		Inflow	0.26 (44%)	0	Outflow	0.13 (23%)	0	
		Total	0.58	0	Total	0.58	0	
	Lake	Resuspension	0.06 (27%)	-75	Deposition	0.20 (92%)	-34	
		Particulate inflow	0.14 (62%)	-13	Particulate Outflow	0.02 (7%)	-83	
		Total	0.22	-46	Total	0.22	-46	
Option 5 Combination	Canal	Particulate inflow	0.07 (17%)	-63	Deposition	0.20 (53%)	-31	
		Inflow	0.32 (83%)	+23	Particulate outflow	0.04 (11%)	-71	
		Total	0.38	-34	Outflow	0.13 (34%)	-2	
					Total	0.38	-88	
	Lake	Particulate inflow	0.05 (64%)	-67	Deposition	0.05 (66%)	-82	
		Inflow	0.03 (33%)	+338	Particulate Outflow	0.02 (28%)	-74	
		Total	0.08	-80	Total	0.08	-80	

**TABLE A-2 con't: Comparison of Anthracene Process Rates
for Baseline Conditions and Remedial Scenarios**

Scenario	Location		Contributions to Sediment (kg/y)	+/- Baseline (%)		Losses from Sediment (kg/y)	+/- Baseline (%)
Baseline	Canal	Deposition	0.29 (100%)	-		Burial	21.50 (99%)
		Total	0.29	-		Total	21.83
	Lake	Deposition	0.30 (100%)	-		Degradation	5.38 (58%)
		Total	0.30	-		Burial	3.70 (40%)
						Total	9.32
							-
Option 1 Sediment Capping	Canal	Deposition	0.22 (100%)	-25		Burial	0.22 (99%)
		Total	0.22	-25		Total	0.22
	Lake	Deposition	0.10 (100%)	-69		Degradation	0.01 (10%)
		Total	0.10	-69		Burial	0.05 (87%)
						Total	0.05
							-99
Option 2 Sediment Traps	Canal	Deposition	0.28 (100%)	-5		Burial	13.15 (81%)
		Total	0.28	-5		Resuspension	2.89 (18%)
						Total	16.19
	Lake	Deposition	0.31 (100%)	0		Degradation	5.38 (58%)
		Total	0.31	0		Resuspension	3.77 (41%)
						Total	9.27
Option 3 Dredging	Canal	Deposition	0.22 (100%)	-26		Burial	0.22 (99%)
		Total	0.22	-26		Total	0.22
	Lake	Deposition	0.09 (100%)	-69		Degradation	0.01 (22%)
		Total	0.09	-69		Burial	0.05 (75%)
						Total	0.06
							-99
Option 4 Wetland	Canal	Deposition	0.29 (100%)	0		Burial	21.54 (99%)
		Total	0.29	0		Total	21.83
	Lake	Deposition	0.20 (100%)	-34		Degradation	5.38 (59%)
		Total	0.20	-34		Burial	3.70 (44%)
						Total	9.14
							-30
Option 5 Combination	Canal	Deposition	0.20 (100%)	-31		Burial	0.20 (99%)
		Total	0.20	-31		Total	0.20
	Lake	Deposition	0.05 (100%)	-82		Degradation	0.02 (62%)
		Total	0.05	-82		Burial	0.01 (37%)
						Total	0.03
							-100

APPENDIX B

**MODEL SPREADSHEET FOR
CANAL AND LAKE STEADY-STATE
BASELINE CONDITIONS FOR
BAP AND ANTHRACENE**

Steady-state Conditions

MOHAWK CANAL B/A P BASELINE CONDITIONS

LAKE DIMENSIONS

water/surface area (m2)	* AW	11000.00	(Gore & Storrie Ltd., 1995a)
water depth (m)	* HW	0.890	(Ecological Services for Planning, 1994a)
water volume (m3)	VW	7.59E+03	
sediment-water area (m2)	* AS	11000.00	(Gore & Storrie Ltd., 1995a)
active sed. depth (m)	* HS	0.25	(Gore & Storrie Ltd., 1995a)
active sed. volume (m3)	VS	2750.00	
WATER FLOWS (m3/h)			
rain rate (mm/y)	* RAIN	855.00	(Gore & Storrie Ltd., 1995a)
inflow (m3/h)	* GWI	130.00	(Gore & Storrie Ltd., 1995a)
stormsewers (m3/h)	* GWIT	162.00	(Gore & Storrie Ltd., 1995a)
total outflow (m3/h)	* GWO	354.00	(Gore & Storrie Ltd., 1995a)
evaporation (mm/y)	* EVAP	728.00	(Gore & Storrie Ltd., 1995a)
total inflow (land based) (m3/h)	GWT	292.00	
PATICLE FLOWS AND MOVEMENT			
water part. inflow (mg/L)	* CSPINN	600	(calculated from Gore & Storrie Ltd., 1995a)
particle inflow stormsewers (mg/L)	* CSPTIN	100	(calculated from Gore & Storrie Ltd., 1995a)
Vol. Wgt. Avg.	CSPIN	322.60	
particle outflow (mg/L)	* CSPOUT	490	(calculated from Gore & Storrie Ltd., 1995a)
sed. burial (g/m2/d)	* BUR	745	(estimated based on sed. depth, yrs to accultuate, etc., then adjusted using Zn data)
sed. resuspension (g/m2/d)	* RES	5	(estimated based on sed. depth, yrs to accultuate, etc., then adjusted using Zn data)
sed. deposition (g/m2/d)	DEP	750	(estimated based on sed. depth, yrs to accultuate, etc., then adjusted using Zn data)
ORGANIC CONTENT			
OC - suspended inflow particles (g/g)	* ORGI	0.1	(estimated)
OC - sediment particles (g/g)	* ORGS	0.1	(Ecological Services for Planning, 1994a)
OC - suspended particles (g/g)	* ORGP	0.2	(estimated)
PARTICLE CONCENTRATIONS			
water (kg/L)	DENW	1	
part. conc. aerosols (ug/m3)	* CFQ	30	(Mackay, 1991 and Ling et al., 1993)
density aerosols (g/cm3)	* DENQ	1.5	(Ling et al., 1993)
vol. frac aerosols	VFQ	2.00E-11	
conc. suspended particles (mg/L)	* CSP	490	(Ecological Services for Planning, 1994a)
density suspended particles (g/cm3)	* DENP	1.310	(Mackay, 1991)
vol. frac suspended particles	VFP	0.00037	
vo. fraction inflow part.	VFI	2.46E-04	
density sediment (g/cm3)	* DENS	1.3	(Golder Associates, 1994)
sediment porosity	* VFS	0.95	(estimated)

* indicates data input, no * indicates a calculation

MOHAWK LAKE QWASI EQUIVALENCE MODEL
Steady-state Conditions

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MOHAWK CANAL B(a)P

BASELINE CONDITIONS

CHEMICAL CHARACTERISTICS

Physical Chemical Properties							
system temperature (deg. cel.)	* TC	25	(Ling et al., 1993)				
system temperature (K)							
molecular mass/weight (g/mol)	* WMO	252	(Ling et al., 1993)				
water solubility (g/m3)	* SOLY	0.0020	(Ling et al., 1993)				
vapour pressure (Pa)	* VP	6.00E-08	(Ling et al., 1993)				
log octanol water part.coef.(Kow)	* LKOW	6.32	(Ling et al., 1993)				
melting point (deg. cel.)	* TM	179	(Ling et al., 1993)				
Degradation Half life							
water (hours)	* TDW	10000	(Ling et al., 1993)				
sediment (hours)	* TDS	30000	(Ling et al., 1993)				
Chemical Transport Parameters							
Atmospheric Deposition							
deposition velocity (cm/s)	* VDEP*	0.3	(Ling et al., 1993)				
deposition velocity (m/h)	VDEP*	10.8					
scavenging ratio	* Q	200000	(Ling et al., 1993)				
Diffusive Transport							
volatilization air-side (m/h)	* KVA	1	(Ling et al., 1993)				
volatilization water side (m/h)	* K VW	0.01	(Ling et al., 1993)				
water sediment mol. diffusivity (cm2/s)	* DIFW	4.24E-06					
sediment water path lenght (m)	* DELMY	0.001					

CALCULATIONS

KOW							
KOW	KOW	2089296.13					
absolute temperature (K)	TK	298					
melting point (K)	TMK	452					
gas constant	R	8.314					
Henry's law constant (Pa.m3/mol)	* H	0.00783	(Ling et al., 1993)				
Mass Tranfer Coefficients							
volailization overall water side (m/h)	KV	3.16E-06					
sediment water diffusion (m/h)	KT	2.74752000E-06					
Rate Constants							
water degradation	KW	6.93E-05					
sediment degradation	KS	2.31E-05					
Partition Coefficients (dimensionless)							
air-water	KPAW	3.16E-06					
aerosol-air	KPAQ	3.34E+15					
susp part.-water	KPPW	2.24E+05					
inflow part.-water	KPPI	1.12E+05					
sediment-water	KPSW	1.11E+05					

MOHAWK LAKE QWASI AQUIVALENCE MODEL

Steady-state Conditions

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MOHAWK CANAL B(a)P

BASELINE CONDITIONS

FUGACITY (Z) VALUES (mol/m3 Pa)

Z water (ZW)	ZW	1					
Z air (ZA)	ZA	3.16E-06					
Z aerosols (ZQ)	ZQ	1.06E+10					
Z inflow suspended particles	ZPI	1.12E+05					
Z suspended (water) particles (ZP)	ZP	2.24E+05					
Z resuspended sediment particles (ZR)	ZR	1.11E+05					
Z sediment particles (ZS)	ZS	1.11E+05					
Z bulk air (air plus aerosols)	ZBA	2.11E-01					
Z bulk water lake (water plus particles)	ZBW	8.49E+01					
Z bulk water inflow (water plus particles)	ZBWI	2.86E+01					
Z bulk sed (sed. plus pore water)	ZBS	1.06E+05					

G VALUES

Water Flow							
inflow (m3/h)	GI	2.92E+02					
outflow (m3/h)	GJ	3.54E+02					
rain (m3/h)	GM	1.07E+00					
evaporation (m3/h)	GE	9.14E-01					
Atmospheric Deposition							
wet particle deposition (m3/h)	GC	4.29E-06					
dry particle deposition (m3/h)	GQ	2.38E-06					
Particle Flow							
inflow (g/h)	GX*	1.75E+05					
inflow (m3/h)		1.34E-01					
outflow (g/h)	GY*	1.73E+05					
outflow (m3/h)		1.32E-01					
Particle Movement							
deposition (g/h)	GD*	3.44E+05					
deposition (m3/h)		2.62E-01					
resuspension (g/h)	GR*	2.29E+03					
resuspension (m3/h)		1.76E-03					
burial (g/h)	GB*	3.41E+05					
burial (m3/h)		2.63E-01					

D VALUES (m3/h)

(TRANSPORT AND TRANSFORMATION)

Water Flow							
inflow	DI	2.92E+02					
outflow	DJ	3.54E+02					
Particle Flow							
inflow	DX	1.50E+04					
outflow	DY	2.97E+04					
Atmospheric Deposition							
rain dissolution	DM	1.07E+00					
wet deposition	DC	4.53E+04					
dry deposition	DQ	2.51E+04					
Particle movement							
deposition	DD	5.89E+04					
resuspension	DR	1.96E+02					
burial	DB	2.92E+04					
Dissolved Chemical Movement							
volatilization	DV	3.48E-02					
sed-water diffusion	DT	3.02E-02					
Chemical Reaction							
water degradation	DW	4.47E+01					
sediment degradation	DS	6.72E+03					

MOHAWK LAKE QWASI EQUIVALENCE MODEL
Steady-state Conditions

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MOHAWK CANAL B(a)P

BASELINE CONDITIONS

STEADY STATE MASS BALANCE CALCULATIONS

Input Initial Concentrations

bulk air (ng/m3)	CA	0.005	(Ling et al., 1993)
water inflow (ng/L)	CI	104	(Aquafor Beech, 1994)
water (ng/L)	CWE		
sediments (ng/g)	CSS		
direct emissions (kg/yr)	EWG		

Calculation of Initial Equivalences

air (mol/m3)	QA	9.39E-14
water inflow (mol/L)	QI	1.44E-08
water (mol/L)	QWE	0.00E+00
sediments (mol/g)	QSS	0.00E+00
direct emissions (mol/h)	QWM	0.00E+00

Mass Balance for Water & Sediment Equivalence

water equivalence (mol/m3)	QWW	2.49E-09
sediment equivalence (mol/m3)	QSW	4.05E-09
Direct emissions (kg/y)	EW	0.00E+00

CONCENTRATIONS AND AMOUNTS

	equivalence mol/m3	concentration mol/m3	concentration	unit	amount kg	amount %
Air	9.39E-14	2.97E-19	0.00	ng/m3		
aerosol	9.39E-14	1.98E-14	0.00	ng/m3		
rain	9.39E-14	3.97E-08	1.00	ng/L		
dissolved water	2.49E-09	2.49E-09	0.83	ng/L	0.00	0.00
suspended part	2.49E-09	5.58E-04	107.35	ng/g		0.00
/unit water	2.49E-09	2.09E-07	52.60	ng/L	0.00	0.13
pore water	4.05E-09	4.05E-09	1.02E+00	ng/L	1.40E-07	0.00
sediment	4.05E-09	4.51E-04	8.74E+01	ng/g	2.97E-01	99.86
bulk air	9.39E-14	1.98E-14	0.00	ng/m3		0.00
bulk water	2.49E-09	2.11E-07	53.23	ng/L	0.00	0.14
bulk sediment	4.05E-09	4.28E-04	84.00	ng/g	0.30	99.86
TOTAL					0.30	100.00

PROCESS RATES (kg/yr)

rain dissolution	2.23E-10					
wet deposition	9.40E-06					
dry deposition	5.20E-06					
atmospheric deposition	1.46E-05					
dissolved inflow	0.01					
particle inflow	0.48					
inflow	0.49					
dissolved outflow	0.00					
particle outflow	0.16					
outflow	0.17					
air-water volatilization	7.21E-12					
water-air volatilization	1.91E-07					
net water-air volatilization	1.91E-07					
water-sediment diffusion	1.66E-07					
sed-water diffusion	2.70E-07					
net sediment-water diffusion	1.04E-07					
sediment deposition	0.32					
sediment resuspension	0.00					
net water-sediment deposition	0.32					
sediment burial	0.26					
water degradation	0.00					
sediment degradation	0.06					
total degradation	0.06					
Mass Balance Check						
inouts - water	0.49					
outputs - water	0.49					
inouts - sediment	0.32					
outputs - sediment	0.32					

MOHAWK LAKE QWASI AQUIVALENCE MODEL
Steady-state Conditions

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MOHAWK CANAL B(a)P BASELINE CONDITIONS

SUMMARY	kg/y	% of inputs				
emissions	0.00E+00	0.00E+00				
atmospheric contributions	1.44E-05	2.96E-03				
total inflow	0.49	100.00				
total inputs to water	0.49	100.00				
net inputs to sediment	0.32	66.04				
degradation in water	0.00	0.05				
total outflow	0.17	33.91				
total outputs from water	0.49	100.00				
% sediment retention	53.70					
% export	33.91					
persistence (years)	0.61					
Contributions to water	kg/yr	%				
emissions	0.00	0.00				
inflow	0.01	1.90				
part inflow	0.48	97.74				
atmospheric deposition	0.00	0.00				
volatilization	0.00	0.00				
resuspension	0.00	0.36				
s-w diffusion	0.00	0.00				
Total	0.49	100.00				
Losses from Water						
outflow	0.00	0.40				
part outflow	0.16	33.39				
w degradation	0.00	0.05				
volatilization	0.00	0.00				
deposition	0.32	66.16				
w-s diffusion	0.00	0.00				
total	0.49	100.00				
Contributions to sediments						
deposition	0.32	100.00				
w-s diffusion	0.00	0.00				
Total	0.32	100.00				
Losses from Sediments						
resuspension	0.00	0.54				
s-w diffusion	0.00	0.00				
s degradation	0.06	18.58				
burial	0.26	80.88				
Total	0.32	100.00				

MOHAWK LAKE QWASI AQUIVALENCE MODEL
Steady--state Conditions

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RESUSPENSION (LAND BASED) MOHAWK LAKE		MOHAWK LAKE	B(a)P	BASELINE CONDITIONS			
LAKE CHARACTERISTICS							
LAKE DIMENSIONS							
water/surface area (m2)	* AW	139000.00					
water depth (m)	* HW	1.75					
water volume (m3)	VW	243250.00					
sediment--water area (m2)	* AS	139000.00					
active sed. depth (m)	* HS	0.25					
active sed. volume (m3)	VS	34750.00					
WATER FLOWS (m3/h)							
rain rate (mm/y)	* RAIN	855.00					
inflow (m3/h)	* GWI	354.00					
stormsewers (m3/h)	* GWIT	22.00					
total outflow (m3/h)	* GWO	383.00					
evaporation (mm/y)	* EVAP	728.00					
total inflow (land based) (m3/h)	GWT	376.00					
PATICLE FLOWS AND MOVEMENT							
water part. inflow (mg/L)	* CSPINN	490.00					
particle inflow stormsewers (mg/L)	* CSPTIN	100.00					
Vol. Wgt. Avg.	CSPIN	467.18					
particle outflow (mg/L)	* CSPOUT	550.00					
sed. burial (g/m2/d)	* BUR	117.50					
sed. resuspension (g/m2/d)	* RES	7.5					
sed. deposition (g/m2/d)	DEP	125					
ORGANIC CONTENT							
OC -- suspended inflow particles (g/g)	* ORGI	0.06					
OC -- sediment particles (g/g)	* ORGS	0.06					
OC -- suspended particles (g/g)	* ORGP	0.09					
PARTICLE CONCENTRATIONS							
water (kg/L)	DENW	1					
part. conc. aerosols (ug/m3)	* CFQ	30					
density aerosols (g/cm3)	* DENQ	1.5					
vol. frac aerosols	VFQ	2.00E-11					
conc. suspended particles (mg/L)	* CSP	500					
density suspended particles (g/cm3)	* DENP	1.400					
vol. frac suspended particles	VFP	0.0003571					
vo. fraction inflow part.	VFI	0.0003337006079					
density sediment (g/cm3)	* DENS	1.3					
sediment porosity	* VFS	0.95					
* indicates data input, no * indicates a calculation							

MOHAWK LAKE QWASI EQUIVALENCE MODEL							
Steady-state Conditions							
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		MOHAWK LAKE	B(a)P	BASELINE CONDITIONS			
CHEMICAL CHARACTERISTICS							
Physical Chemical Properties							
system temperature (deg. cel.)	* TC	25					
system temperature (K)							
molecular mass/weight (g/mol)	* WMO	252					
water solubility (g/m3)	* SOLY	0.0020					
vapour pressure (Pa)	* VP	6.00E-08					
log octanol water part.coef.(Kow)	* LKOW	6.32					
melting point (deg. cel.)	* TM	179					
Degradation Half life							
water (hours)	* TDW	10000					
sediment (hours)	* TDS	30000					
Chemical Transport Parameters							
Atmospheric Deposition							
deposition velocity (cm/s)	* VDEP*	0.2					
deposition velocity (m/h)	VDEP*	7.2					
scavenging ratio	* Q	200000					
Diffusive Transport							
volatilization air-side (m/h)	* KVA	1					
volatilization water side (m/h)	* KVV	0.01					
water sdiment mol. diffusivity (cm2/s)	* DIFW	4.24E-06					
sediment water path lenght (m)	* DELMY	0.001					
CALCULATIONS							
KOW	KOW	2089296.130854					
absolute temperature (K)	TK	298					
melting point (K)	TMK	452					
gas constant	R	8.314					
Henry's law constant (Pa.m3/mol)	* H	0.00783					
Mass Tranfer Coefficients							
volailization overall water side (m/h)	KV	3.16E-06					
sediment water diffusion (m/h)	KT	2.74752000E-06					
Rate Constants							
water degradation	KW	6.93E-05					
sediment degradation	KS	2.31E-05					
Partition Coefficients (dimensionless)							
air-water	KPAW	3.16E-06					
aerosol-air	KPQA	3.34E+15					
susp.part.-water	KPPW	1.08E+05					
inflow part-water	KPPI	7.20E+04					
sediment-water	KPSW	6.68E+04					

MOHAWK LAKE QWASI AQUIVALENCE MODEL

Steady-state Conditions

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MOHAWK LAKE

B(a)P

BASELINE CONDITIONS

FUGACITY (Z) VALUES (mol/m³ Pa)

Z water (ZW)	ZW	1
Z air (ZA)	ZA	3.16E-06
Z aerosols (ZQ)	ZQ	1.06E+10
Z inflow suspended particles	ZPI	7.20E+04
Z suspended (water) particles (ZP)	ZP	1.08E+05
Z resuspended sediment particles (ZR)	ZR	6.68E+04
Z sediment particles (ZS)	ZS	6.68E+04
Z bulk air (air plus aerosols)	ZBA	2.11E-01
Z bulk water lake (water plus particles)	ZBW	3.95E+01
Z bulk water inflow (water plus particles)	ZBWI	2.50E+01
Z bulk sed (sed. plus pore water)	ZBS	6.35E+04

G VALUES

Water Flow		
inflow (m ³ /h)	GI	3.76E+02
outflow (m ³ /h)	GJ	3.83E+02
rain (m ³ /h)	GM	1.36E+01
evaporation (m ³ /h)	GE	1.16E+01
Atmospheric Deposition		
wet particle deposition (m ³ /h)	GC	5.43E-05
dry particle deposition (m ³ /h)	GQ	2.00E-05
Particle Flow		
inflow (g/h)	GX*	1.84E+05
inflow (m ³ /h)		1.32E-01
outflow (g/h)	GY*	2.11E+05
outflow (m ³ /h)		1.50E-01
Particle Movement		
deposition (g/h)	GD*	7.24E+05
deposition (m ³ /h)		5.17E-01
resuspension (g/h)	GR*	4.34E+04
resuspension (m ³ /h)		3.34E-02
burial (g/h)	GB*	6.81E+05
burial (m ³ /h)		5.23E-01

D VALUES (m³/h)

(TRANSPORT AND TRANSFORMATION)

Water Flow		
inflow	DI	3.76E+02
outflow	DJ	3.83E+02
Particle Flow		
inflow	DX	9.47E+03
outflow	DY	1.62E+04
Atmospheric Deposition		
rain dissolution	DM	1.36E+01
wet deposition	DC	5.73E+05
dry deposition	DQ	2.11E+05
Particle movement		
deposition	DD	5.58E+04
resuspension	DR	2.23E+03
burial	DB	3.50E+04
Dissolved Chemical Movement		
volatilization	DV	4.39E-01
sed-water diffusion	DT	3.82E-01
Chemical Reaction		
water degradation	DW	6.67E+02
sediment degradation	DS	5.10E+04

MOHAWK LAKE QWASI AQUIVALENCE MODEL

Steady – state Conditions

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MOHAWK LAKE B(a)P

BASELINE CONDITIONS

STEADY STATE MASS BALANCE CALCULATIONS

Input Initial Concentrations			
bulk air (ng/m3)	* CA	0.005	(Ling et al., 1993)
water inflow (ng/L)	* CI	52.60	(represents canal water conc., as estimated by canal baseline model)
water (ng/L)	* CWE		
sediments (ng/g)	* CSS		
direct emissions (kg/yr)	* EWG		
Calculation of Initial Aquivalences			
air (mol/m3)	QA	9.39E-14	
water inflow (mol/L)	QI	8.35E-09	
water (mol/L)	QWE	0.00E+00	
sediments (mol/g)	QSS	0.00E+00	
direct emissions (mol/h)	EWM	0.00E+00	
Mass Balance for Water & Sediment Aquivalence			
water equivalence (mol/m3)	QWW	1.15E-09	
sediment equivalence (mol/m3)	QSW	7.26E-10	
Direct emissions (kg/y)	EW	0.00E+00	

CONCENTRATIONS AND AMOUNTS

	aquivalence mol/m3	concentration mol/m3	concentration	unit	amount kg	amount %
Air	9.39E-14	2.97E-19	0.00	ng/m3		
aerosol	9.39E-14	1.98E-14	0.00	ng/m3		
rain	9.39E-14	3.97E-09	1.00	ng/L		
dissolved water	1.15E-09	1.15E-09	0.29	ng/L	0.00	0.02
suspended part	1.15E-09	1.24E-04	22.29	ng/g		0.00
/unit water	1.15E-09	4.42E-08	11.14	ng/L	0.00	0.67
pore water	7.26E-10	7.26E-10	1.83E-01	ng/L	3.18E-07	0.00
sediment	7.26E-10	4.85E-05	9.41E+00	ng/g	4.04E-01	99.32
bulk air	9.39E-14	1.98E-14	0.00	ng/m3		0.00
bulk water	1.15E-09	4.54E-08	11.43	ng/L	0.00	0.68
bulk sediment	7.26E-10	4.61E-05	9.04	ng/g	0.40	99.32
TOTAL					0.41	100.00

PROCESS RATES (kg/yr)

rain dissolution	2.81E-09					
wet deposition	1.19E-04					
dry deposition	4.38E-05					
atmospheric deposition	1.63E-04					
dissolved inflow	0.01					
particle inflow	0.17					
inflow	0.18					
dissolved outflow	0.00					
particle outflow	0.04					
outflow	0.04					
air – water volatilization	9.11E-11					
water – air volatilization	1.11E-06					
net water – air volatilization	1.11E-06					
water – sediment diffusion	9.67E-07					
sed – water diffusion	6.12E-07					
net sediment – water diffusion	-3.55E-07					
sediment deposition	0.14					
sediment resuspension	0.00					
net water – sediment deposition	0.14					
sediment burial	0.06					
water degradation	0.00					
sediment degradation	0.08					
total degradation	0.08					
Mass Balance Check						
inputs – water						
outputs – water						
inputs – sediment						
outputs – sediment						

MOHAWK LAKE QWASI EQUIVALENCE MODEL

Steady-state Conditions

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MOHAWK LAKE B(a)P

BASELINE CONDITIONS

SUMMARY

kg/y

% of inputs

emissions	0.0000	0.0000				
atmospheric contributions	0.0002	0.0890				
total inflow	0.18	99.91				
total inputs to water	0.18	100.00				
net inputs to sediment	0.14	75.88				
degradation in water	0.00	0.93				
total outflow	0.04	23.19				
total outputs from water	0.18	100.00				
% sediment retention	30.89					
% export	23.19					
persistence (years)	2.24					
Contributions to water	kg/yr	%				
emissions	0.00	0.00				
inflow	0.01	3.74				
part inflow	0.17	94.24				
atmospheric deposition	0.00	0.09				
volatilization	0.00	0.00				
resuspension	0.00	1.93				
s-w diffusion	0.00	0.00				
Total	0.19	100.00				
Losses from Water						
outflow	0.00	0.52				
part outflow	0.04	22.21				
w degradation	0.00	0.91				
volatilization	0.00	0.00				
deposition	0.14	76.35				
w-s diffusion	0.00	0.00				
total	0.19	100.19				
Contributions to sediments						
deposition	0.14	100.00				
w-s diffusion	0.00	0.00				
Total	0.14	100.00				
Losses from Sediments						
resuspension	0.00	2.53				
s-w diffusion	0.00	0.00				
s degradation	0.08	57.79				
burial	0.06	39.67				
Total	0.14	100.00				

MOHAWK LAKE QWASI EQUIVALENCE MODEL

Steady-state Conditions

H:\USER\SEATON\QWASI\ANTMOD1.WK3

		MOHAWK CANAL	Anthracene	BASELINE CONDITIONS			
LAKE CHARACTERISTICS							
LAKE DIMENSIONS							
water/surface area (m2)	* AW	11000.00	(Gore & Storrie Ltd., 1995a)				
water depth (m)	* HW	0.690	(Ecological Services for Planning, 1994a)				
water volume (m3)	VW	7.59E+03					
sediment-water area (m2)	* AS	11000.00	(Gore & Storrie Ltd., 1995a)				
active sed. depth (m)	* HS	0.25	(Gore & Storrie Ltd., 1995a)				
active sed. volume (m3)	VS	2750.00					
WATER FLOWS (m3/h)							
rain rate (mm/y)	* RAIN	855.00	(Gore & Storrie Ltd., 1995a)				
inflow (m3/h)	* GWI	130.00	(Gore & Storrie Ltd., 1995a)				
stormsewers (m3/h)	* GWIT	162.00	(Gore & Storrie Ltd., 1995a)				
total outflow (m3/h)	* GWO	354.00	(Gore & Storrie Ltd., 1995a)				
evaporation (mm/y)	* EVAP	728.00	(Gore & Storrie Ltd., 1995a)				
total inflow (land based) (m3/h)	GWT	292.00					
PARTICLE FLOWS AND MOVEMENT							
water part. inflow (mg/L)	* CSPINN	600	(calculated from Gore & Storrie Ltd., 1995a)				
particle inflow stormsewers (mg/L)	* CSPTIN	100	(calculated from Gore & Storrie Ltd., 1995a)				
Vol. Wgt. Avg.	CSPIN	322.60					
particle outflow (mg/L)	* CSPOUT	490	(calculated from Gore & Storrie Ltd., 1995a)				
sed. burial (g/m2/d)	* BUR	745	(estimated based on sed. depth, yrs to accuulate, etc., then adjusted using Zn data)				
sed. resuspension (g/m2/d)	* RES	5	(estimated based on sed. depth, yrs to accuulate, etc., then adjusted using Zn data)				
sed. deposition (g/m2/d)	DEP	750	(estimated based on sed. depth, yrs to accuulate, etc., then adjusted using Zn data)				
ORGANIC CONTENT							
OC - suspended inflow particles (g/g)	* ORGI	0.1	(estimated)				
OC - sediment particles (g/g)	* ORGS	0.1	(Ecological Services for Planning, 1994a)				
OC - suspended particles (g/g)	* ORGP	0.2	(estimated)				
PARTICLE CONCENTRATIONS							
water (kg/L)	DENW	1					
part. conc. aerosols (ug/m3)	* CFQ	30	(Mackay, 1991 and Ling et al., 1993)				
density aerosols (g/cm3)	* DENQ	1.5	(Ling et al., 1993)				
vol. frac aerosols	VFQ	2.00E-11					
conc. suspended particles (mg/L)	* CSP	490	(Ecological Services for Planning, 1994a)				
density suspended particles (g/cm3)	* DENP	1.310	(Mackay, 1991)				
vol. frac suspended particles	VFP	0.00037					
vo. fraction inflow part.	VFI	2.46E-04					
density sediment (g/cm3)	* DENS	1.3	(Golder Associates, 1994)				
sediment porosity	* VFS	0.95	(estimated)				
* indicates data input, no * indicates a calculation							

MOHAWK LAKE QWASI AQUIVALENCE MODEL

Steady-state Conditions

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MOHAWK CANAL Anthracene BASELINE CONDITIONS

CHEMICAL CHARATERISTICS

Physical Chemical Properties

system temperature (deg. cel.)	* TC	25	(Mackay et al., 1992)
system temperature (K)			
molecular mass/weight (g/mol)	* WMO	178.24	(Mackay et al., 1992)
water solubility (g/m3)	* SOLY	0.0750	(Mackay et al., 1992)
vapour pressure (Pa)	* VP	1.44E-03	(Mackay et al., 1992)
log octanol water part.coef.(Kow)	* LKOW	4.45	(Mackay et al., 1992)
melting point (deg. cel.)	* TM	216.2	(Mackay et al., 1992)

Degradation Half life

water (hours)	* TDW	1000	(Mackay et al., 1992)
sediment (hours)	* TDS	1000000	(Mackay et al., 1992)

Chemical Transport Parameters

Atmospheric Deposition			
deposition velocity (cm/s)	* VDEP*	0.3	Ling et al., 1993
deposition velocity (m/h)	VDEP*	10.8	
scavenging ratio	* Q	200000	Ling et al., 1993
Diffusive Transport			
volatilization air-side (m/h)	* KVA	2.9	(Mackay et al., 1992)
volatilization water side (m/h)	* KVV	0.001	(Mackay et al., 1992)
water sdiment mol. diffusivity (cm2/s)	* DIFW	4.27E-06	(Mackay et al., 1992)
sediment water path lenght (m)	* DELMY	0.001	

CALCULATIONS

KOW	KOW	26183.83	
absolute temperature (K)	TK	298	
melting point (K)	TMK	489.2	
gas constant	R	8.314	
Henry's law constant (Pa.m3/mol)	* H	6	(Mackay et al., 1992)

Mass Tranfer Coefficients

volailization overall water side (m/h)	KV	8.75E-04	
sediment water diffusion (m/h)	KT	2.76696000E-06	

Rate Constants

water degradation	KW	6.93E-04	
sediment degradation	KS	6.93E-07	

Partition Coefficients (dimensionless)

air-water	KPAW	2.42E-03	
aerosol-air	KPQA	3.25E+11	
susp.part.-water	KPPW	3.03E+03	
inflow part-water	KPPI	1.51E+03	
sediment-water	KPSW	1.50E+03	

MOHAWK LAKE QWASI EQUIVALENCE MODEL							
Steady-state Conditions							
H:\USER\SEATOM\QWASI\ANTMOD1.WK3							
		MOHAWK CANAL	Anthracene	BASELINE CONDITIONS			
FUGACITY (Z) VALUES (mol/m3 Pa)							
Z water (ZW)	ZW	1					
Z air (ZA)	ZA	2.42E-03					
Z aerosols (ZQ)	ZQ	7.87E+08					
Z inflow suspended particles	ZPI	1.51E+03					
Z suspended (water) particles (ZP)	ZP	3.03E+03					
Z resuspended sediment particles (ZR)	ZR	1.50E+03					
Z sediment particles (ZS)	ZS	1.50E+03					
Z bulk air (air plus aerosols)	ZBA	1.82E-02					
Z bulk water lake (water plus particles)	ZBW	2.13E+00					
Z bulk water inflow (water plus particles)	ZBWI	1.37E+00					
Z bulk sed (sed. plus pore water)	ZBS	1.43E+03					
G VALUES							
Water Flow							
inflow (m3/h)	GI	2.92E+02					
outflow (m3/h)	GJ	3.54E+02					
rain (m3/h)	GM	1.07E+00					
evaporation (m3/h)	GE	9.14E-01					
Atmospheric Deposition							
wet particle deposition (m3/h)	GC	4.29E-06					
dry particle deposition (m3/h)	GQ	2.38E-06					
Particle Flow							
inflow (g/h)	GX*	1.75E+05					
inflow (m3/h)		1.34E-01					
outflow (g/h)	GY*	1.73E+05					
outflow (m3/h)		1.32E-01					
Particle Movement							
deposition (g/h)	GD*	3.44E+05					
deposition (m3/h)		2.62E-01					
resuspension (g/h)	GR*	2.29E+03					
resuspension (m3/h)		1.76E-03					
burial (g/h)	GB*	3.41E+05					
burial (m3/h)		2.63E-01					
D VALUES (m3/h)							
(TRANSPORT AND TRANSFORMATION)							
Water Flow							
inflow	DI	2.92E+02					
outflow	DJ	3.54E+02					
Particle Flow							
inflow	DX	2.02E+02					
outflow	DY	4.01E+02					
Atmospheric Deposition							
rain dissolution	DM	1.07E+00					
wet deposition	DC	3.38E+03					
dry deposition	DQ	1.87E+03					
Particle movement							
deposition	DD	7.94E+02					
resuspension	DR	2.65E+00					
burial	DB	3.95E+02					
Dissolved Chemical Movement							
volatilization	DV	9.63E+00					
sed-water diffusion	DT	3.04E-02					
Chemical Reaction							
water degradation	DW	1.12E+01					
sediment degradation	DS	2.72E+00					

MOHAWK LAKE QWASI EQUIVALENCE MODEL							
Steady-state Conditions							
H:\USER\SEATON\QWASIVANTMOD1.WK3		MOHAWK CANAL	Anthracene	BASELINE CONDITIONS			
STEADY STATE MASS BALANCE CALCULATIONS							
Input Initial Concentrations							
bulk air (ng/m3)	* CA	0.06	(McVetty and Hites, 1988)				
water inflow (ng/L)	* CI	137	(Aquafor Beech, 1994)				
water (ng/L)	* CWE						
sediments (ng/g)	* CSS						
direct emissions (kg/yr)	* EWG						
Calculation of Inital Aquivalances							
air (mol/m3)	QA	1.85E-11					
water inflow (mol/L)	QI	5.60E-07					
water (mol/L)	QWE	0.00E+00					
sediments (mol/g)	QSS	0.00E+00					
direct emissions (mol/h)	EWM	0.00E+00					
Mass Balance for Water & Sediment Aquivalence							
water equivalence (mol/m3)	QWW	1.77E-07					
sediment equivalence (mol/m3)	QSW	3.52E-07					
Direct emissions (kg/y)	EW	0.00E+00					
CONCENTRATIONS AND AMOUNTS							
	aquivalence mol/m3	concentration mol/m3	concentration	unit	amount kg	amount %	
Air	1.85E-11	4.49E-14	0.01	ng/m3			
aerosol	1.85E-11	2.92E-13	0.05	ng/m3			
rain	1.85E-11	5.84E-08	10.40	ng/L			
dissolved water	1.77E-07	1.77E-07	31.55	ng/L		0.00	0.10
suspended part	1.77E-07	5.36E-04	72.91	ng/g			0.00
/unit water	1.77E-07	2.00E-07	35.73	ng/L		0.00	0.11
pore water	3.52E-07	3.52E-07	62.67	ng/L		8.62E-06	0.00
sediment	3.52E-07	5.28E-04	72.42	ng/g		2.46E-01	99.79
bulk air	1.85E-11	3.37E-13	0.06	ng/m3			0.00
bulk water	1.77E-07	3.77E-07	67.27	ng/L		0.00	0.21
bulk sediment	3.52E-07	5.02E-04	69.60	ng/g		0.25	99.79
TOTAL						0.25	100.00
PROCESS RATES (kg/yr)							
rain dissolution	3.11E-08						
wet deposition	9.78E-05						
dry deposition	5.41E-05						
atmospheric deposition	1.52E-04						
dissolved inflow	0.26						
particle inflow	0.18						
inflow	0.43						
dissolved outflow	0.10						
particle outflow	0.11						
outflow	0.21						
air-water volatilization	2.79E-07						
water-air volatilization	2.66E-03						
net water-air volatilization	2.66E-03						
water-sediment diffusion	8.41E-06						
sed-water diffusion	1.67E-05						
net sediment-water diffusion	8.30E-06						
sediment deposition	0.22						
sediment resuspension	0.00						
net water-sediment deposition	0.22						
sediment burial	0.22						
water degradation	0.00						
sediment degradation	0.00						
total degradation	0.00						
Mass Balance Check							
inouts - water	0.43						
outputs - water	0.43						
inouts - sediment	0.220						
outputs - sediment	0.220						

MOHAWK LAKE QWASI AQUIVALENCE MODEL

Steady-state Conditions

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MOHAWK CANAL Anthracene BASELINE CONDITIONS

SUMMARY	kg/y	% of inputs				
emissions	0.00E+00	0.00E+00				
atmospheric contributions	-2.51E-03	-5.84E-01				
total inflow	0.43	100.58				
total inputs to water	0.43	100.00				
net inputs to sediment	0.22	50.74				
degradation in water	0.00	0.72				
total outflow	0.21	48.54				
total outputs from water	0.43	100.00				
% sediment retention	50.39					
% export	48.54					
persistence (years)	0.57					
Contributions to water	kg/yr	%				
emissions	0.00	0.00				
inflow	0.26	58.83				
part inflow	0.18	40.79				
atmospheric deposition	0.00	0.04				
volatilization	0.00	0.00				
resuspension	0.00	0.33				
s-w diffusion	0.00	0.00				
Total	0.43	100.00				
Losses from Water						
outflow	0.10	22.55				
part outflow	0.11	25.53				
w degradation	0.00	0.71				
volatilization	0.00	0.61				
deposition	0.22	50.59				
w-s diffusion	0.00	0.00				
total	0.43	100.00				
Contributions to sediments						
deposition	0.22	100.00				
w-s diffusion	0.00	0.00				
Total	0.22	100.00				
Losses from Sediments						
resuspension	0.00	0.66				
s-w diffusion	0.00	0.01				
s degradation	0.00	0.68				
burial	0.22	98.65				
Total	0.22	100.00				

Steady-state Conditions

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MOHAWK LAKE		Anthracene	BASELINE CONDITIONS				
LAKE CHARACTERISTICS							
LAKE DIMENSIONS							
water/surface area (m2)	* AW	139000.00					
water depth (m)	* HW	1.75					
water volume (m3)	VW	243250.00					
sediment-water area (m2)	* AS	139000.00					
active sed. depth (m)	* HS	0.25					
active sed. volume (m3)	VS	34750.00					
WATER FLOWS (m3/h)							
rain rate (mm/y)	* RAIN	855.00					
inflow (m3/h)	* GWI	354.00					
stormsewers (m3/h)	* GWIT	22.00					
total outflow (m3/h)	* GWO	383.00					
evaporation (mm/y)	* EVAP	728.00					
total inflow (land based) (m3/h)	GWT	376.00					
PARTICLE FLOWS AND MOVEMENT							
water part. inflow (mg/L)	* CSPINN	490.00					
particle inflow stormsewers (mg/L)	* CSPTIN	100.00					
Vol. Wgt. Avg.	CSPIN	467.18					
particle outflow (mg/L)	* CSPOUT	550.00					
sed. burial (g/m2/d)	* BUR	117.50					
sed. resuspension (g/m2/d)	* RES	7.5					
sed. deposition (g/m2/d)	DEP	125					
ORGANIC CONTENT							
OC - suspended inflow particles (g/g)	* ORGI	0.06					
OC - sediment particles (g/g)	* ORGS	0.06					
OC - suspended particles (g/g)	* ORGP	0.09					
PARTICLE CONCENTRATIONS							
water (kg/L)	DENW	1					
part. conc. aerosols (ug/m3)	* CFQ	30					
density aerosols (g/cm3)	* DENQ	1.5					
vol. frac aerosols	VFQ	2.00E-11					
conc. suspended particles (mg/L)	* CSP	500					
density suspended particles (g/cm3)	* DENP	1.400					
vol. frac suspended particles	VFP	0.0003571					
vo. fraction inflow part.	VFI	0.0003337006079					
density sediment (g/cm3)	* DENS	1.3					
sediment porosity	* VFS	0.95					
* indicates data input, no * indicates a calculation							

MOHAWK LAKE QWASI AQUIVALENCE MODEL

Steady-state Conditions

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MOHAWK LAKE Anthracene BASELINE CONDITIONS

CHEMICAL CHARATERISTICS

Physical Chemical Properties							
system temperature (deg. cel.)	* TC	25	(Mackay et al., 1992)				
system temperature (K)							
molecular mass/weight (g/mol)	* WMO	178.24	(Mackay et al., 1992)				
water solubility (g/m3)	* SOLY	0.0750	(Mackay et al., 1992)				
vapour pressure (Pa)	* VP	1.44E-03	(Mackay et al., 1992)				
log octanol water part.coef.(Kow)	* LKOW	4.45	(Mackay et al., 1992)				
melting point (deg. cel.)	* TM	216.2	(Mackay et al., 1992)				
Degradation Half life							
water (hours)	* TDW	1000	(Mackay et al., 1992)				
sediment (hours)	* TDS	1000000	(Mackay et al., 1992)				
Chemical Transport Parameters							
Atmospheric Deposition							
deposition velocity (cm/s)	* VDEP*	0.3	(Ling et al., 1993)				
deposition velocity (m/h)	VDEP*	10.8					
scavenging ratio	* Q	200000	(Ling et al., 1993)				
Diffusive Transport							
volatilization air-side (m/h)	* KVA	2.9	(Mackay et al., 1992)				
volatilization water side (m/h)	* KVV	0.001	(Mackay et al., 1992)				
water sdiment mol. diffusivity (cm2/s)	* DIFW	4.27E-06	(Mackay et al., 1992)				
sediment water path lenght (m)	* DELMY	0.001					

CALCULATIONS

KOW	KOW	28183.829312645					
absolute temperature (K)	TK	298					
melting point (K)	TMK	489.2					
gas constant	R	8.314					
Henry's law constant (Pa.m3/mol)	* H	0.00783					
Mass Tranfer Coefficients							
volalilization overall water side (m/h)	KV	9.08E-06					
sediment water diffusion (m/h)	KT	2.76696000E-06					
Rate Constants							
water degradation	KW	6.93E-04					
sediment degradation	KS	6.93E-07					
Partition Coefficients (dimensionless)							
air-water	KPAW	3.16E-06					
aerosol-air	KPOA	3.25E+11					
susp.part.-water	KPPW	1.46E+03					
inflow part-water	KPPI	9.71E+02					
sediment-water	KPSW	9.01E+02					

MOHAWK LAKE QWASI EQUIVALENCE MODEL
Steady-state Conditions

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MOHAWK LAKE Anthracene BASELINE CONDITIONS

FUGACITY (Z) VALUES (mol/m3 Pa)

Z water (ZW)	ZW	1					
Z air (ZA)	ZA	3.16E-06					
Z aerosols (ZQ)	ZQ	1.03E+06					
Z inflow suspended particles	ZPI	9.71E+02					
Z suspended (water) particles (ZP)	ZP	1.46E+03					
Z resuspended sediment particles (ZR)	ZR	9.01E+02					
Z sediment particles (ZS)	ZS	9.01E+02					
Z bulk air (air plus aerosols)	ZBA	2.37E-05					
Z bulk water lake (water plus particles)	ZBW	1.52E+00					
Z bulk water inflow (water plus particles)	ZBWI	1.32E+00					
Z bulk sed (sed. plus pore water)	ZBS	8.56E+02					

G VALUES

Water Flow							
inflow (m3/h)	GI	3.76E+02					
outflow (m3/h)	GJ	3.83E+02					
rain (m3/h)	GM	1.36E+01					
evaporation (m3/h)	GE	1.16E+01					
Atmospheric Deposition							
wet particle deposition (m3/h)	GC	5.43E-05					
dry particle deposition (m3/h)	GQ	3.00E-05					
Particle Flow							
inflow (g/h)	GX*	1.84E+05					
inflow (m3/h)		1.32E-01					
outflow (g/h)	GY*	2.11E+05					
outflow (m3/h)		1.50E-01					
Particle Movement							
deposition (g/h)	GD*	7.24E+05					
deposition (m3/h)		5.17E-01					
resuspension (g/h)	GR*	4.34E+04					
resuspension (m3/h)		3.34E-02					
burial (g/h)	GB*	6.81E+05					
burial (m3/h)		5.23E-01					

D VALUES (m3/h)
(TRANSPORT AND TRANSFORMATION)

Water Flow							
inflow	DI	3.76E+02					
outflow	DJ	3.83E+02					
Particle Flow							
inflow	DX	1.26E+02					
outflow	DY	2.19E+02					
Atmospheric Deposition							
rain dissolution	DM	1.36E+01					
wet deposition	DC	5.57E+01					
dry deposition	DQ	3.08E+01					
Particle movement							
deposition	DD	7.53E+02					
resuspension	DR	3.01E+01					
burial	DB	4.72E+02					
Dissolved Chemical Movement							
volatilization	DV	1.26E+00					
sed-water diffusion	DT	3.85E-01					
Chemical Reaction							
water degradation	DW	2.56E+02					
sediment degradation	DS	2.06E+01					

MOHAWK LAKE QWASI EQUIVALENCE MODEL						
Steady – state Conditions						
H:\USER\SEATON\QWASIVANTMOD1.WK3		MOHAWK LAKE	Anthracene	BASELINE CONDITIONS		
STEADY STATE MASS BALANCE CALCULATIONS						
Input Initial Concentrations						
bulk air (ng/m3)	* CA	0.06	(McVeety and Hites, 1988)			
water inflow (ng/L)	* CI	35.73	(represents canal water conc., as estimated by canal baseline model)			
water (ng/L)	* CWE					
sediments (ng/g)	* CSS					
direct emissions (kg/yr)	* EWG					
Calculation of Inital Aquivalances						
air (mol/m3)	QA	1.42E – 08				
water inflow (mol/L)	QI	1.51E – 07				
water (mol/L)	QWE	0.00E + 00				
sediments (mol/g)	QSS	0.00E + 00				
direct emissions (mol/h)	EWM	0.00E + 00				
Mass Balance for Water & Sediment Aquivalence						
water aquivalence (mol/m3)	QWW	4.95E – 08				
sediment aquivalence (mol/m3)	QSW	7.14E – 08				
Direct emissions (kg/y)	EW	0.00E + 00				
CONCENTRATIONS AND AMOUNTS						
	aquivalence mol/m3	concentration mol/m3	concntration	unit	amount kg	amount %
Air	1.42E – 08	4.49E – 14	0.01	ng/m3		
aerosol	1.42E – 08	2.92E – 13	0.05	ng/m3		
rain	1.42E – 08	7.26E – 08	12.93	ng/L		
dissolved water	4.95E – 08	4.95E – 08	8.83	ng/L	0.00	0.56
suspended part	4.95E – 08	7.21E – 05	9.18	ng/g		0.00
/unit water	4.95E – 08	2.58E – 08	4.59	ng/L	0.00	0.29
pore water	7.14E – 08	7.14E – 08	1.27E + 01	ng/L	2.21E – 05	0.01
sediment	7.14E – 08	6.43E – 05	8.82E + 00	ng/g	3.79E – 01	99.14
bulk air	1.42E – 08	3.37E – 13	0.06	ng/m3		0.00
bulk water	4.95E – 08	7.53E – 08	13.42	ng/L	0.00	0.86
bulk sediment	7.14E – 08	6.11E – 05	8.48	ng/g	0.38	99.14
TOTAL					0.38	100.00
PROCESS RATES (kg/yr)						
rain dissolution	3.01E – 04					
wet deposition	1.24E – 03					
dry deposition	6.84E – 04					
atmospheric deposition	2.22E – 03					
dissolved inflow	0.09					
particle inflow	0.03					
inflow	0.12					
dissolved outflow	0.03					
particle outflow	0.02					
outflow	0.05					
air – water volatilization	2.80E – 05					
water – air volatilization	9.77E – 05					
net water – air volatilization	6.97E – 05					
water – sediment diffusion	2.98E – 05					
sed – water diffusion	4.29E – 05					
net sediment – water diffusion	1.31E – 05					
sediment deposition	0.06					
sediment resuspension	0.00					
net water – sediment deposition	0.05					
sediment burial	0.05					
water degradation	0.02					
sediment degradation	0.00					
total degradation	0.02					
Mass Balance Check						
inouts – water						
outputs – water						
inouts – sediment						
outputs – sediment						

MOHAWK LAKE QWASI EQUIVALENCE MODEL
Steady-state Conditions

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	MOHAWK LAKE	Anthracene	BASELINE CONDITIONS				
SUMMARY	kg/y	% of inputs					
emmissions	0.0000	0.0000					
atmospheric contributions	0.0022	1.7738					
total inflow	0.12	98.23					
total inputs to water	0.12	100.00					
net inputs to sediment	0.05	45.25					
degradation in water	0.02	16.34					
total outflow	0.05	38.41					
total outputs from water	0.12	100.00					
% sediment retention	43.36						
% export	38.41						
persistence (years)	3.15						
Contributions to water	kg/yr	%					
emmissions	0.00	0.00					
inflow	0.09	71.26					
part inflow	0.03	24.21					
atmospheric deposition	0.00	1.78					
volatilization	0.00	0.02					
resuspension	0.00	2.69					
s-w diffusion	0.00	0.03					
Total	0.12	100.00					
Losses from Water							
outflow	0.03	23.75					
part outflow	0.02	13.58					
w degradation	0.02	15.88					
volatilization	0.00	0.08					
depostion	0.06	46.68					
w-s diffusion	0.00	0.02					
total	0.12	100.12					
Contributions to sediments							
depsoion	0.06	99.95					
w-s diffusion	0.00	0.05					
Total	0.06	100.00					
Losses from Sediments							
resuspension	0.00	5.76					
s-w diffusion	0.00	0.07					
s degradation	0.00	3.94					
burial	0.05	90.22					
Total	0.06	100.00					

